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ON RIVER GAUGING AND THE DOUBLE FLOAT.

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THE *double float*, used so extensively by Messrs. Humphrey and Abbot,* in their investigations made between the years 1850 and 1860 on the Mississippi River, has proved in their hands to be a valuable means of finding current velocities. In the best form used by them, it consisted of a hollow cylinder (paint keg with bottom knocked out), ballasted so as to have a slight sinking tendency, for the lower part, and connected by a cord, which allowed it to sink to a certain depth, to a surface float only partly submerged, formed of a tin ellipsoid bearing upon a wire a small flag to assist in observing it.† The method adopted for using these floats was to put out several, one after another, from a boat stationed in the river and considerably above the points of observation. The time of passage of the floats between two parallel cross sections of the river was taken by the aid of two transit instruments, one stationed in each section; each float was observed across each section by both transits, so as to be able to locate the points of passage by triangulation. The sections were usually about 200 feet apart. These Mississippi gauging operations appear to be the first of importance in which the double float was used as the prevailing means for finding the velocity; though Mr. Chas. Ellet had previously used them to some extent on the same river.

Though the double float was suggested some 300 years ago, and employed to a limited extent, yet till quite recently it seems to have been used only for obtaining surface velocity,* the lower float being submerged only a few inches or perhaps feet. They were made of two balls of wax connected by a thread, and each properly ballasted; the object of their use having been explicitly to get surface velocity, but used in lieu of single floats at the surface for the purpose of reaching such a depth as to avoid influence of air currents upon the surface, and at the same time not exceeding that depth which would give the true surface velocity.

Subsurface, velocities, as such, were first observed by aid of Pitot's tube about in the year 1730. These experiments made known the true law of velocities, previously supposed to increase with depth.† This tube was also used to some extent and improved by Dubuat‡

* Gen. A. A. Humphrey's, Chief U. S. Engineers, and Gen. H. L. Abbot, Navy U. S. Engineers.

† See Report on the Physics and Hydraulics of the Mississippi River, by Humphrey and Abbot, p. 224.

* Encyclopedia Britannica, 8 ed. vol. xii. p. 142, and Morins Hydralique, p. 114.

† Memoirs of the French Academy for 1732 and D'Aubuisson's Hydraulique, art. 151.

‡ Bossut's Hydraulique, § 572, and D'Aubuisson's Hydraulique, art. 148.

and Mallet, and subsequently extensively used and greatly improved by Darcy.* In the form adopted by Darcy it is a valuable instrument, though, for a single observation, it only gives the velocity at the moment a certain stopcock is turned, which fixes the height of the water column until observed.

The early experiments with Pitot's tube on the Seine, not only overturned the theories previously advanced by Guglielmini, and supported by others, but made known the fact that the true mean velocity of a stream can only be obtained by measuring the velocity at various parts of the cross section.

Various instruments were subsequently devised for measuring the velocity of river currents.

Bossut† and also Dubuat‡ used a paddle or float wheel with floats parallel to the axis, and so placed when in action that the floats dip an inch or two into the surface of the stream. This was long since abandoned as the floats were too much influenced by the air.

Zendrini, Ximenes, Michelotti, Gerstner and Eytelwein,§ used the Hydrometric Pendulum, a ball suspended by a thread, in gauging the River Po. In use the ball was lowered into the current and the inclination of the thread noted.

Brünnings improved the Tachometer or pressure plate, and used it on the Rhine in Holland, and Ximenes on the Arno.‖ It was also used by Lorgna, Michelotti and Palette. Boileau describes a tachometer balanced by a spring instead of weights.

Racourt¶ used an instrument resembling a ship's log in important gauging operations on the Neva at St. Petersburg.

Woltmann's mill, or meter, however, is the instrument which has been most generally employed, and is believed by most hydraulic engineers to be superior to all other means ever used for determining the volocity of running water.**

M. Lapointe* adopted a Woltmann's meter wheel in his *gauging cylinder*, the registering apparatus being detached and carried outside by aid of level gearing. This arrangement was used in elaborate gaugings at the Powdermill *du Bouchet*, and also at the *Bassins de Chaellot.* This instrument is described at length and elaborately illustrated on plate 2, by Morin in his Hydraulique, and recommended for use. Woltmann's mill has been extensively used by Defountaine on the Rhine, including many points of observation, and by Baumgarten and Darcy.† Baumgarten recommends it very highly.‡

Krayenhoff, Buffon and Destrem used floats of the form of rods or poles so loaded that they rode nearly vertical in the stream, extending from the surface nearly to the bottom, aiming, by this means, to obtain the mean velocity at once of the longitudinal vertical section of the stream.§ This plan was perfected by J. B. Francis, of Lowell, Mass., who used loaded tin tubes two inches in diameter in straight and uniform flumes.‖ These experiments are among the most elaborate and trustworthy to be found recorded, and prove beyond a doubt the great value and precision of such floats in cases where the bed of the stream is sufficiently uniform. These floats give very nearly the mean velocity for the depth of the tube, without regard to the form of vertical curve of velocities. They would give it exactly if the resistance of a medium to solid bodies passing through it varied as the first power of the velocity. But varying as the second power, the true mean differs from the observed velocity of tube as pointed out by Mr. Francis. When the tube extends nearly to the bottom, calculation shows that for that depth the true mean is less than tube velocity by about five per cent.

Hirn used sheet floats in small canals which nearly filled the whole transverse section, and thus obtained, at once, the approximate mean velocity of the whole stream.¶

* Morin's Hydraulique, p. 131.
† Bossut's Hydraulique, § 665.
‡ Morin's Hydraulique, p. 98, and D'Aubuisson's Hydraulique, art. 146.
§ Encylopedia Britannica, vol. xii., p. 142, and Weisbach Mech. and Eng., p. 1,000.
‖ Brewster, D'Aubuisson, arts. 152 and 153, and Weisbach, Mech. and Eng., p. 1,001.
¶ Encyclopedia Britannica, vol. xii., p. 144.
** Enc. Brit., vol. xii., p. 144. Morin's Hydraul., p. 111. D'Aubuisson, art. 150.

* Morin's Hydraul., pp. 99 and 100.
† Morin's Hydraul., p. 11, and D'Aubuisson, art. 152.
‡ Pants et Chaussées for 1847.
§ Humphrey's and Abbot's report on the Mississippi, p. 202.
‖ Lowell's Hydraulic Experiment, p. 172.
¶ Humphrey's and Abbot's Miss. report, p. 203.

Those gaugings which are conceded to be the most important of Europe were made with Woltmann's mill, the tachometer, and Racourt's ship's log. Of these instruments, the former receives the highest favor, and has been the most extensively used.

In this country, the double float and the Krayenhoff tube float, have been most used in gaugings of importance, though various current meters have been employed from time to time, and recently they have been rapidly gaining favor. A peculiar telegraphic meter was devised and used by Asst. D. F. Henry,* under Gen. W. F. Raynolds, Supt. U. S. Lake Survey, in extensive gaugings of the rivers of the Great Lakes undertaken in 1868–9. This meter is illustrated and described at length in the "Journal of the Franklin Institute," for May, 1869, p. 305. In these gaugings the double float, modeled after that used on the Mississippi, was first adopted, but afterwards abandoned as far inferior to the Henry meter.

This sketch of the various means which have been employed for measuring current velocities in river gaugings of importance, together with the names of those hydraulic engineers who adopted them in individual cases, and of those authors who described and used them, has been given that we may form an opinion of the relative merits of the different instruments based on the estimate placed upon them by men of eminence. It is clearly indicated that a current meter or *moulinet* of some form stands in most universal favor, the Woltmann's mill being one of the best.

It is evident that those qualities which should be possessed by a current measurer are: 1st, accuracy and constancy in indications; 2d, that it give the mean velocity for the time during which a single observation is taken; and 3d, that it be convenient and reliable. That these qualities are found possessed in the highest degree in a well constructed current meter is made clearer by noticing a few points of peculiarity in the different instruments, and of difficulties in the way of their use. In all streams there is more or less of eddying, and of unaccountable meandering local currents continually shifting the water in lateral directions. These are liable to take effect upon the instrument causing it to record a greater velocity than that which it evidently should, viz.: the horizontal component. Pitot's tube in its best form, as for instance it was left by Darcy gives, for one observation, the component parallel to the tube at its open end at the instant the column is fixed. The fluctuations of the column, however, are reduced considerably by reducing the bore of the tube at some part to a small calibre, by which means the height of column is made to represent approximately the mean height for a time more or less extended, though at best the interval will be short. This requires numerous raisings and lowerings of the instrument. In the tachometer we have difficulty with the variation of the pressure against the plate. The ship's log is free from this, but it is liable to be led about in various directions by the transverse currents, giving an erroneous result. The double floats are likely to be subject each to such lateral currents and one float never found above the other; this inclines the connecting cord decreasing the depth. The Woltmann's mill, if directed by a vane, will head in various directions and not give the up-and-down stream component of velocity. In the illustrations, however, this meter is represented as attached rigidly to a pole or rod, which, when rightly directed, will give the desired component. The illustration of Henry's meter represents it as directed by a vane. The same is true of Baumearten's Velocimeter. These should be rigidly held in a position directed up stream, unless it can be shown that the lateral movements of the water have no appreciable effect to turn it out of its true course when directed by a vane.

The objections above noticed are seen to be unavoidable in every case, except the current meter, in its different forms. As the current meter is one of the most convenient instruments for use, there seems to be sufficient cause for the prevailing preference for its use.

In selecting a current meter, the best form, of course, should be adopted. It must necessarily have some form of register. This is usually attached to the instrument and submerged with it, and generally, in fact, regarded as part of the

* Now Chief Engineer of the Detroit Water Works.

instrument. But we find an exception to this in the Henry meter. The meter wheel, in this, has simply to break an electric circuit at each revolution, the same being recorded by an electric register at the surface. This separation of the wheel-work and relief of the meter wheel from the load of driving them is very advantageous, for the resistance of the wheel-work in water of variable degrees of grittiness must be different at different times, causing irregular indications. Also the register being at the surface, it is not necessary to raise the meter at each observation. From these facts it appears that the Henry telegraphic meter or moulinet possesses advantages which render it superior to all other means yet tried for measuring the velocity of running water in large rivers.

It is much to be regretted that the gauging operations on the lake rivers were prematurely stopped, preventing the more thoroughly testing of this instrument. Enough was done, however, to indicate its superiority over double floats, with which it was put in experimental comparison, and which finally led to the abandonment of the floats and the adoption of the meter.

Careful comparative observations of the floats and meter indicated almost perfect agreement at the surface, but below this the floats gave too high velocities, increasing with depth. These discrepancies led to the discovery of errors due to floats which Mr. Henry pointed out in substance as follows*: First, the upper float drags the lower increasing its velocity. Second, the pressure of current against the connecting cord increases the velocity of the lower float; and Third, these effects incline the cord down stream and raise the lower float. The comparisons indicate that a correction should be applied to gaugings made with double floats by deducting about six per cent.

The necessity of a float correction becoming evident, the writer was requested to make a mathematical investigation of the matter, the results of which were forwarded to Mr. Henry some time after and published in his pamphlet on the flow of water. Though the analysis is somewhat complex, the correction found confirms the result obtained by experimental comparison of the float and meter.

In the analytical problem a vertical curve of velocities was required in order to determine the pressure of current against the connecting cord. This was assumed elliptical and agreeing with the observed float velocities. This assumption was perceived to be illogical, because it rendered implicit the curve which it sought to correct. But this was done because the true curve was unknown, the first result being regarded only as an approximation, giving a new curve which could be again used for a second approximation, &c.

The table below, taken from Mr. Henry's pamphlet, contains the first corrections, and the ordinates of the resulting curve, found by aid of the formulas, for an example of double float measurements taken from the report of Humphrey's and Abbot, p. 230. The observations were taken on the Mississippi River at Carrollton, La., in 1851.

COMPUTED CORRECTIONS FOR FLOAT OBSERVATIONS.

Depth of float, ft.	Observed velocity.	Computed velocity.	Difference
0	4.230	4.230	0.000
18	4.298	4.298	0.000
36	4.346	4.346	0.000
54	4.274	4.250	0.024
72	4.158	4.015	0.143
90	4.053	3.785	0.268
102	3.948	3.275	0.673
110	Bottom.	2.670	

These figures show quite large corrections for the greater depths, and for the mean velocity a correction of about 3.8 per cent. This correction falls somewhat short of that obtained by Mr. Henry in his direct comparison of the float and meter, a result which may be partly attributed to the fact that the second or third corrections were not computed.

Since the publication of Mr. Henry's pamphlet, the problem has been thoroughly reviewed with a view to simplifying the formulas, and of obtaining more complete corrections. Rigorous methods led to complex formulas, for

* Pamphlet on the Flow of Water, by D. F. Henry, p. 16, and Jour. Tr, Inst. for 1871.

which reason approximate methods have, in part, been adopted, not, however, without comparing in each case with the exact formulas, the results obtained by computation.

As these formulas are of great value in discussing the double float system, and lead to a knowledge of the best form of double float for practical use, they will be given here, together with an example to show their application in computing corrections.

The nature of the problem is as follows: The float combination, consisting of the upper and lower floats and connecting cord, is supposed to be observed when moving down stream with a common velocity. The weight of the floats and cord are supposed to be known, and also the approximate form of the vertical curve of velocities. Required the velocity of the water at the lower float.

Let v_0 = velocity of water at surface of stream.

v_c = velocity of current at any depth y.

v_1 = common velocity of float combination.

v_2 = velocity of water at lower float.

v_m = maximum velocity of water in the vertical section.

W = weight of lower float when immersed, and also assumed equal to the tension of the connecting cord at any point.

a_1 = area of upper float presented to current.

a_2 = area of lower float presented to current.

r = radius of connecting cord.

c_1 = coefficient found by experiment giving pressure of current upon units section of upper float at units velocity.

c_2 = similar coefficient for lower float.

c = similar coefficient for connecting cord.

x and y = coördinates of curve of connecting cord, origin at upper float.

d = depth of stream in the longitudinal section considered.

For a cylinder* $c = .75$, and resistance $= .75\ a\ v^2$.

For a sphere $c = .50$, and resistance $= .50\ a\ v^2$.

The velocity of the water past the upper float is $v_0 - v_1$, and hence the pressure of the water upon it is

$$P = A_1 C_1 (v_0 - v_1)^2 \text{ lbs.} \qquad (1)$$

For the lower float the velocity is $v_1 - v_2$, and the pressure upon it is

$$P = A_2 C_2 (v_1 - v_2)^2 \text{ lbs.} \qquad (2)$$

Dividing the cord into elementary lengths dy, an elementary area will be $2\,r\,dy$, and hence an elementary pressure against it is

$$P = C\ 2\,r\,dy\,(v_0 - v_1)^2 \qquad (3)$$

And the total pressure upon the cord from the surface to the depth y is

$$\Sigma P = 2\,c\,r \int_0^y (v_0 - v)^2\,dy \qquad (4)$$

It is to be observed that the difference $v_0 - v_1$ changes its sign between the surface and lower float, while the square does not; so that the integral between these limits would express the sum of the upstream and downstream pressures instead of difference, which is required. This expression is of the same form as that for the *moment of inertae*, for which the sum is reqired instead of difference, and hence extreme limits admissible. For the present case our limits would be the surface and depth where $v_0 = v_1$, and then the latter limit and depth of lower float. The difference of the numerical values of these two quantities is then to be taken. This leads to such complicated expressions that they have only been used to check the approximate formulas, and insure their trustworthiness.

The velocity $(v_0 - v_1)$ of the water past the cord at various depths y, sometimes positive and sometimes negative, is the distance from an axis A B to the true curve of velocities D B E, Fig. 1. If now the mean ordinate to this curve be found, it may be introduced into a formula, to give an approximate value of the pressure of current against the cord. Let this be represented by $(v_n - v_1)$.

* Rankine's Applied Mechanics, p. 599, and Bennett's Morin's Mechanics, p. 375.

Then

$$\Sigma P = 2\,c\,r\,(v_n - v_1)^2 y \text{ nearly.} \quad (5)$$

To determine this mean ordinate we have

$$(v_n - v_1)y = \int_0^y (v_0 - v_1)dy. \quad (6)$$

To find an expresssion for the equation of the curve of cord, we may take moments about any point of it, of the forces acting upon the combination above that point: thus

$$Wx = (y - \bar{y})\,\Sigma P + a_1 c_1\,(v_0 - v_1)^2 y. \quad (7)$$

In which $\bar{y}$ is the depth of the center of pressure upon that part of cord considered. To get a simple expression for others, it is assumed to be at the center of gravity of the area below A D to the depth considered. Hence

$$y\,(v_n - v_1)\bar{y} = \int_0^y (v_0 - v_1)y\,dy \quad (8)$$

To find the true velocity of water v_2 at the lower float, we have by equating the horizontal forces acting upon the float combination,

$$a_2 c_2\,(v_1 - v_2)^2 = a_1 c_1\,(v_0 - v_1)^2 + \Sigma P. \quad (9)$$

Assuming that the vertical curve of velocities is a parabola with its axis horizontal and some depth below the surface of stream, as done by Humphrey and Abbot and others, we have

$$(y - nd)^2 = 2\,P\,(v_m - v_0) \quad (10)$$

for its equation, the origin being taken at the surface of the stream, and at a distance v_m from the vertex. The principal axis of the parabola is at a depth nd, and $2P$ is the parameter of the parabola. The curve might be assumed elliptical, or of any other form.

Combining (10) with (5), (6), (8) and (9), we get

$$(v_n - v_1)y = \int_0^y \left((v_m - v_1) - \frac{(y - nd)^2}{2P}\right)dy$$

$$= \left\{ (v_m - v_1)y - \frac{(y - nd)^3}{6P} - \frac{n^3 d^3}{6P} \right\}$$

$$\Sigma P = 2\,cr \left\{ (v_m - v_1) - \frac{(y - nd)^3}{6Py} - \frac{n^3 d^3}{6Py} \right\}^2 \quad (11)$$

$$\bar{y} = \frac{y}{2} \left\{ \frac{(v_m - v_1) - \frac{1}{P}\left(\frac{y}{2} - \frac{2nd}{3}\right)^3 - \frac{n^3 d^3}{18P}}{(v_m - v_1) - \frac{(y - nd)^3}{6Py} - \frac{n^3 d^3}{6Py}} \right\} \quad (12)$$

$$v_1 - v_2 = \left\{ \frac{a_1 c_1}{a_2 c_2}\,(v_0 - v_1) + \frac{\Sigma P}{a_2 c_2} \right\}^{\frac{1}{2}} \quad (13)$$

$$x = \frac{y - \bar{y}}{W}\,\Sigma P + \frac{a_1 c_1}{W}\,(v_0 - v_1)^2 y \quad (14)$$

It is evident that in all these formulas which involve the action of the current upon the cord or connecting line, such values of nd and $2P$ should be used as belong to the true curve of velocities; and not such as are found from the curve of observed float velocities. This effect may be secured in two ways; first, by a series of approximating curves as above mentioned; or second, by assuming a guess curve or parabola, and proving it by a computation, using nd and $2P$ as belonging to it. The latter is in effect the same as the former—we guess at the first approximation instead of calculating it.

In proving the guess curve two computations must be made, one to determine the amount the lower float is raised by the inclination of cord, and another for the difference of velocity of the lower float and of the current in which that float is dragged. The first is represented in Fig. 1 by C F and the second by F G. When these are obtained, they are to be plotted as shown in Fig. 1, on the same diagram with the parabolas. Starting from C, if G pulls on the guess curve, that curve is the one sought, unless its figure be changed by similar computations and plottings for other points.

The guess curve is assumed, for convenience sake, to be a parabola obtained by multiplying all the vertical ordinates, y, of the primitive parabola by a certain constant fraction m. If, for instance, A C = 70 and A B = 50, $m = \frac{50}{70}$. By so doing it is to be observed that B is the point where the velocity of the stream is the same as the observed velocity of the floats for the particular cord length, or supposed depth A C. This amounts to estimating the position of B and finding m. Then our guess parabola has the equation

$$(y—m\,nd)^2=M^2\,2\,P\,(v_m-v_c)$$

which can be easily shown. If this is done, then these values of $m\,nd$, and $m^2\,2\,P$ are to be used for nd and 2P in equations (11) and (12.)

If the parabola thus found is believed to represent, with sufficient accuracy, the real curve of velocities, its mean ordinate, for a depth d, is to be compared with the mean ordinate of the primitive parabola for a like depth, to obtain the correction, per centum, for the float observations in the vertical longitudinal section of the stream considered. It will, however, be better to compute several corrections for different heights in the vertical, in the manner shown in Fig. 1, after which a curve, parabolic, elliptical, or otherwise, should be found which best agrees with the points, and it adopted for the true curve of velocities.

The problem is thus solved as far as proposed in this article. The formulas are approximate, but differ so very slightly in their results from the thoroughly rigorous formulas first worked out, as proved by very laborious computions, that the discussions and examples following will be regarded as consequences of the rigorous formulas themselves.

The formulas furnish the following hints which should be observed in conducting float observations:

1ST—CONNECTING CORD.

The value of (11) increases directly as r or radius of cord. Hence the line connecting the floats should be reduced to the least possible value to make the pressure upon the cord a minimum. For instance, to reduce the cord from 0.2 of an inch to a wire 0.01 inch in diameter reduces this pressure twentyfold. As ΣP in (13) is the principal part of that equation, we have the velocity correction varying nearly in the direct ratio of the square root of r. And similarly x varies nearly as the first power, $q\,r$. Hence, in every sense it is essential to reduce the diameter of the connecting line to the very minimum. It should, therefore, be a wire, which, for the usual dimensions of the floats, may safely be a hundredth of an inch or less.

2D—BALLASTING.

In (14), W is the weight of the lower float when immersed, or tension of the cord, which shows that to reduce x, the falling back of the lower float, W, should be considerable. If x can be so decreased as to make the rising of the lower float, depending upon the inclination of the cord or line, inconsiderable, three-fourths of the labor of computing corrections would be avoided. This indicates that W should be given as large a value as practicable without unduly increasing the volume of the upper part to support it. Though the latter increases the velocity correction as indicated by (13), still the tenu involving a is usually small compared with the other; and the value of a, whether great or small, makes but little difference with the labor of computing corrections. As W enters no other formula, it is evidently not good policy to make it excessively small. The example given further on will aid in deciding this point.

3D—FORM OF UPPER FLOAT.

It is evident that its form should be that of least resistance, which is a sphere or ellipsoid.

Suppose W to be wholly resisted by the buoyancy of the upper float, the latter without weight, and a spheroid with shortest axis vertical. Let the half depth = h, and the horizontal radius = b, then

$$W=\tfrac{1}{3}.\tfrac{4}{3}.\,\pi\,b^3\,h\,\delta,$$

and

$$a_1=\tfrac{1}{2}\,\pi\,b\,h=\frac{3\,W}{b\,\delta}$$

in which δ is the density of the water, the upper float always being supposed to be half immersed.

Now regarding W as constant, we see that a varies inversely as b the diameter of the float. Hence the upper float should be a large and flat ellipsoid lying on the surface of the water, that a may thereby be reduced to a minimum.

4TH—FORM OF LOWER FLOAT.

As a_2 and c_2 appear only in the denominator of (13), both should be made as large as practicable. A hollow cylinder, like a cask with both top and bottom

knocked out and held upright, would evidently be a good form.

These hints all agree with statements of Gen. H. L. Abbot, in an article in the "Journal of the Franklin Institute,"* as far as made, except he says the upper float should be *minute*. This would require a *very small* value for W, and hence give great danger of the rising of the lower float to an unknown depth, particularly in deep rivers. *Small* would be sufficiently superlative.

AN EXAMPLE.

The following example has been completely worked out to show the application of the formulas in correcting double float velocity measurements; and not only this, but to make clear the necessity either of correcting the float observations or of following the hints brought out by the discussion of the above formulas.

The example selected is of double float observations taken at Vicksburg, Miss., May 13th and Aug. 7th, 1858, on the Mississippi River in a depth of 75 ft., and is found reported in the second table in page 246 of the "Report on the Physics and Hydraulics of the Mississippi River," by Humphrey and Abbot. This example is chosen because the velocity of the river at this point is quite large, for which it is supposed the floats would be most disturbed, and not because the number observations at each depth is few. The sequel, however, shows that the disturbing influence of swift currents is proportionally about the same as for less velocities. The data for this example as appearing on page 246 are given in the following table, together with the ordinates of the parabola which are found to agree best with the float observations.

"SUB-SURFACE VELOCITY OBSERVATIONS UPON THE MISSISSIPPI AT ITS HIGHEST STAGE, THE DEPTH BEING ABOUT 75 FEET."

Depth, ft.	Velocity observed.	Ordinates of Parabola	Difference.
0	7.50	7.50	.000
40	7 54	7.533	+.007
50	7.29	7.380	−.110
60	7.33	7.162	+.168
70	6.82	6.880	−.060

*"Journal Franklin Institute" for May, 1873, p. 308.

Equation (10) gives the ordinates in the third column by making

$$nd=21.283,\ 2\,P=3097.4,\ v_m=7.646.$$

A guess parabola is assumed which starts from the same point at the surface, has the same maximum ordinate v_m, and for which, for any given value of v_o, the value of y, is only $\frac{1}{4}$ that of the above primitive parabola. Hence, for this guess parabola

$$m\,nd=15.2,\ m^2\,2\,P=1580.\quad v_m=7.646,$$

which are to be used for nd and $2\,P$ in the general equations (11) to (14) in proving the guess parabola. The vertical and horizontal corrections C F and and F G, Fig. 1, may be found for any point of supposed depth, say 70 ft. By aid of (14) the values of x, for given depths y, are computed; which are the co-ordinates of the curve the connecting cord assumes when the float combination has settled into equilibrium in the stream. These are given in the table below.

In these computations definite values for W, c, r, a_1, c_1, a_2, and c_2 are required. On page 224 of the Mississippi Report $2r=$ somewhat less than 0.2 inch, say $=.18$ inch$=.015$ ft. : $a_1=.022$ ft. by assuming the float to be the ellipsoid $5\frac{1}{2}$ inches in diameter by $1\frac{1}{2}$ inches deep half immersed, instead of the half inch pine board $5\frac{1}{2}$ inches square, both of which were used in 1858, but which, in this example, is not stated : $a_2=\frac{2}{3}$ ft., it being a keg 8×12 inches. But W is not given in the report, and hence must be estimated. The weight of the tin of ordinary thickness; solder; flag and wire for supporting it; say .25 lb. The semi-ellipsoid would displace .42 lb. of water. Difference$=W=.17$ lb. The values of c are given above. Hence

$$\frac{a_1\,c_1}{a_2\,c_2}=.022,\ 2\,cr=.0112,\quad \frac{a_1\,c_1}{W}=.0815.$$

This curve is plotted to scale in Fig. 2. It is observed to be somewhat "S-shaped," the reversing of the curvature being due to the fact that the lower portion of the cord is itself dragged along more rapidly than the water moves. The lower float is observed to be very far from the position supposed.

TABLE OF CO-ORDINATES OF THE CURVE THE CONNECTING CORD ASSUMES IN THE CURRENT.

Depths in ft. y	Values of x ft.
0	0
10	1.55
20	6.90
30	14.72
40	26.26
50	31.92
60	34.03

Now laying off 70 ft. on the curve, we find the float to be situated at Fig. 1, and at an actual depth of almost exactly 60 feet only, including an excessive lifting of the lower float.

This depth, 60 feet, is now to be used for the actual depth of lower float, y, in (11) and (13), for computing the velocity correction. This is found to be

$$v_1 - v_2 = 0.516 \text{ ft.}$$

Laying this off from F, Fig. 1, brings us exactly to the guess curve; which shows that this curve was correctly assumed, and hence we have one point in the real, or corrected curve of velocities.

The correction found in a similar manner for a cord of 50 ft. length gives the horizontal displacement of float, x, $=2.51$, which is too small to decrease the depth appreciably. Then

$$v_1 - v_2 = 0.187 \text{ ft.}$$

Similarly for a depth of 30 ft.

$$v_1 - v_2 = 0.020.$$

These when plotted ought to give points on the guess parabola, but do not exactly. Plotting them, and working out a parabola which best fits them all, we find

$$nd = 17.32 \quad 2P = 1500. \quad v_m = 7.7.$$

Taking this and proceeding to a second approximation, we get no appreciable change in the position of the curve of velocities. The parabola is the curve which fits them best, confirming in this case the parabolic law of Humphrey and Abbot.

The equation of the correct velocity curve, in which v_c represents the velocity of current for the depth y, is therefore

$$(y - 17.32)^2 = 1500\ (7.7 - v_c)$$

The curve, agreeing best with the float observations from which Messrs. Humphrey and Abbot took their mean, is

$$(y - 21.283)^2 = 3097.4\ (7.646 - v_c)$$

Hence the actual mean velocity of the river at Vicksburg, in the vertical considered, is the mean ordinate of the above corrected parabola for a depth $d = 75$ feet, which, found by an equation like that just preceding (11), is

Correct mean 7.148 ft. per sec.

Mean according to the floats, and as the Mississippi Report would have it, for the vertical considered,

Float mean 7.458,

greater than the true mean by over 4.3 per cent.

This correction does not differ very far, per centum, from that found from the example quoted from Mr. Henry's pamphlet.

I wish to call attention, before passing to the resemblance between the above computed corrections for the Vicksburg observations, and those obtained by Mr. Henry in his experiments on the St. Clair River, both of which are presented in the following: (*See table next page.*)

The table explains itself. Let us compare the columns of differences. These, we observe, are negative down as far as to point of maximum velocity, below which they are positive in both cases, and increase with depth. Though the differences found by meter are greater proportionally at mid-depths,—at points near the bottom they are nearly alike. But by more careful inspection it is seen that the apparent dissimilarity at mid-depth is more seeming than real. The point of maximum velocity is at a greater proportionate depth in the Mississippi velocities than in the St. Clair. At proportionate depths reckoned from this, there is an almost exact similarity in the *pro rata* value of the differences, which fully explains the apparent anomaly, and really exhibits a wonderful conformity of the results. This would indicate that the correction, *per centum*, would be

TABLE OF FLOAT VELOCITIES COMPARED WITH ACTUAL VELOCITIES.

Observations at Vicksburg, Corrects by Calculation.				Observations in St. Clair River, Corrected by Telegraphic Meter.			
Depth feet.	Ordinates of Parabola agreeing with Float Observations	Ordinates of Parabola agreeing with Computed Velocities.	Difference.	Depth feet.	Velocity by Floats.	Velocity by Meter.	Difference.
0	7.500	7.500	.000	0	3.619	3.655	−.036
10	7.605	7.664	−.059	5	3.759	3.782	−.024
20	7.645	7.695	−.050	10	3.703	3.674	+.029
30	7.621	7.593	+.028	15	3.590	3.516	+.074
40	7.533	7.357	+.176	20	3.598	3.405	+.193
50	7.380	6.988	+.392	25	3.637	3.441	+.196
60	7.162	6.486	+.675	35	3.556	3.166	+.390
70	6.880	5.849	+1.031	45	3.542	2.985	+.577
75	Bottom.			50	Bottom.		

greatest in those cases where the maximum velocity of stream is nearest to the surface. In the corrections to the Carrollton gauging, given above, the maximum velocity is at proportionally the same depth as in those of Vicksburg, and we find the correction about the same, *per centum*, regardless of the great difference in velocity of stream.

These examples indicate that in streams where the maximum velocity is at about a fourth of the depth, as in the Mississippi observations, the correction is about 4 per cent.; and where the maximum velocity is at a seventh of the depth, as in the St. Clair experiments, the correction is about 6 per cent.; that is to say, the denominator of the fraction expressing the depth of maximum velocity, is very nearly the *per centum* rate of correction for the gauging.

This rule, if more fully verified by more numerous examples, would only apply in cases where the double float used is patterned after those used on the Mississippi by Humphrey & Abbot. If the conclusions or hints above pointed out as consequences of the general formulas be carefully observed in designing the float, the corrections may be reduced to such inconsiderable quantities as to be overlooked. For instance, if a correction of 4 per cent. arises principally from a cord 0, 2 inches in diameter, a cord a twentieth of that size would require a correction of less than a fourth of the former, or less than one per cent. This is a consequence of (13) and (11), which show that the velocity correction varies nearly as the square root of the diameter of the connecting line.

A wire filament a hundredth of an inch in diameter, connecting the floats, would present to the current, for a depth of 90 feet, an aggregate area of three times that of the upper float of the size and form of the tin ellipsoid used in 1858. This shows the importance of giving attention to reducing the resistance of the connecting line, rather than that of the surface float, particularly for great depths, and also the hopelessness of endeavor of rendering the action of the current upon the line insignificant as compared with the upper float resistance.

Though the dragging action of the upper float upon the lower appears to have been considered while the Mississippi observations were going on, as indicated by the fact that observations were made to ascertain the effect of the wind upon the upper float to drive the combination about; and as also evinced by the reduction of the area presented by the upper float from 12 square inches to 3 square inches between the observations of 1851 and 1858; yet the effect of the connecting cord, nearly a quarter of an inch in diameter, appears to have been entirely ignored.

A cord 0, 2 of an inch in diameter, stretched through a depth of 90 feet,

would present to the current an area of 216 square inches. The largest upper float used presented only 12 square inches, an insignificant quantity comparatively. The largest lower float used was 10×15 inches, presenting an area of 150 square inches, giving a total of both floats of 162 square inches; an area only three-fourths of that of the connecting cord. It is therefore plain that for these depths the cord, itself, must have become the prevailing float instead of the float proper, the observations going on more after the manner of the Krayenhoff pole float type, than according to the double float system, giving, in reality, no idea whatever of the actual velocity of the water at the depth where the lower float was supposed to be. It is difficult to discover how the connecting cord could have escaped the consideration of the Mississippi observers, when the upper float received so much attention, a matter of comparatively no consequence whatever.

Since the appearance of the float and meter comparisons, it has been suggested by several that the connecting line be reduced to a fine wire; and prominent among them is Gen H. L. Abbot* himself, who is supposed to be in a measure responsible for the dimensions of the float combination used on the Mississippi River. As regards the suggestion by Gen. Abbot, coming from a man of his good judgment and experience in the line of river hydraulics, it may be considered as favorably supporting the points made above; and in the light of the above showing, as equivalent to an admission that double floats, modeled after those used on the Mississippi, cannot give the exact velocity.

* Jour. Fr. Inst. for May, 1873, p. 308.

AIR AND VENTILATION.

By W. N. HARTLEY, Esq., F. C. S.

From the "Journal of the Society of Arts."

In the treatment of this subject, I shall be compelled to omit any consideration of the first half of the title, and confine myself to ventilation simply, or I would rather say, to the pollution of air, and rendering of air fit for breathing. When we analyze very carefully the atmosphere we find it consists of one volume of oxygen diluted with four volumes of nitrogen, the oxygen being an active gas, diluted with an inactive gas. Therefore, generally speaking, air has the properties of oxygen somewhat enfeebled. Besides this, we have in air a small quantity of ammonia and a small quantity of carbonic acid; that is the common name, but the scientific name is carbonic anhydride, and it is also called carbon di-oxyde. Now the quantity of carbonic acid, as I shall call it, is only very small, but nevertheless it varies very widely within very small limits. The properties of this gas form the first part of my subject. To begin then with the properties of carbonic acid, there are two which are especially remarkable—one is the very great weight of the gas, and the other is the property it has of extinguishing flame. With regard to the sources of the gas. Before I show its properties, I will show the sources of this gas. First of all, there is combustion; and besides the sources of the gas I shall have to refer to the means by which we detect it when it exists in any considerable quantity in the air, for which purpose lime-water is a very convenient test. To show that carbonic acid is produced by combustion, I place some clear lime-water in a jar in which a gas jet has been burnt, and you see the lime-water becomes turbid in a very short space of time from the separation of the insoluble carbonate of lime. The next source is respiration. This may be easily shown in the same way by the aid of lime-water. Here is an apparatus through which I can draw the air necessary for my respiration. First of all, the air passes through lime-water, and by so passing through lime-water it will show you if there is any considerable amount

of carbonic acid in the air; secondly, the air from the lungs, passes through lime-water again, and that will show whether there is any excess of carbonic acid in the air of the lungs over that in the ordinary air. You will see that in one of these bottles, the one through which the air passed, the lime-water is clear, while that through which my breath passed is turbid, showing that the breath is a source of carbonic acid. Then I have again to show you the properties of this gas when we take care to have it undiluted with air, and in order to get it undiluted with air as much as possible we prepare it from marble, and any strong acid, such as hydro-chloric acid or sulphuric acid. This apparatus is now making carbonic acid, and here is a vessel into which this carbonic acid is evolved. The gas there you see is colorless at any rate. Here is another vessel which also supplies me with a certain amount of carbonic acid, and with this vessel I propose to show you the power that carbonic acid has of extinguishing flame. Both these experiments also explain to you that carbonic acid is a heavy gas; in other words, if the carbonic acid were lighter than air, as there is an opening in the top of this vessel, it would readily escape from such a large jar as this, but as it is a heavy gas, you may remove the top of the vessel, and the carbonic acid will remain in it for a short time. To show that there is carbonic acid in this jar, I will put a lighted taper in it. You see that it is extinguished. But to show it on a large scale, I will take a torch of tow and set fire to it; you see it is at once extinguished in this jar of gas. To show you that it is a heavy gas I will inflate this small balloon with air, and put it into this glass, and we shall see whether the gas is sufficiently heavy to float the balloon. You see it only just floats, half way up the glass; but if I blow a soap bubble it will float on the top of the gas. At any rate, you see these two effects of carbonic acid—first, that it extinguishes flames; and secondly, that it is a very heavy gas. I have to bring before your notice the fact that in the outside air the carbonic acid is so mixed up with the oxygen and nitrogen that the air practically over all parts of the world has the same composition; and, although it has not exactly the same composition, yet the variations are within very small limits. Nevertheless, the air of the mountains on the sea shore of Scotland varies from the air in the streets of London, and this variation, which is occasionally small, you will see is of considerable importance by the tables on the wall. These tables, which are taken from the analysis of Dr. Angus Smith, show not only the variation in the air of towns from the air of the country, but also show the variations between the air of one street and that of another. Here is the air from various places in Scotland on the hills. If this table be read with the first number as a whole number, then we must count it as volumes in 10,000 volumes of air; and that will give us 3.2 volumes in 10,000 of air. At the bottom of the hills it is 3.41 in 10,000. Then we come to London; in the parks and open places the air contains 3.01 volumes of carbonic acid in 10,000; on the Thames 3.43 in 10,000; in the streets 3.8—that was in April, 1864. Later on, in April, 1869, we get the carbonic acid in the streets as 4.39. In Manchester during fogs, 6.79, which is a considerable variation from Scotland on the hills. Then I come to some large numbers, which I will not allude to just now. In this table we have the analysis of air in duplicate, so as to ensure the accuracy of the analysis. In the north, north-east and north-western districts, Dalston, Hoxton, Hackney, St. John's Wood and Belsize Park, we have a series of analyses made, and the average of these, with that of Belsize Park omitted, gives us 4.445 in 10,000. In the west and west-central districts it amounts to 4.115; that is, Woburn Square, Tavistock Square, Regent Street, Oxford Street, Hyde Park and Sloane Street. In the east and east-central it is 4.745 in 10,000. In looking at these tables it must strike anyone that in the part of the town where it is open, consisting of wide streets and squares, with houses thinly inhabited, that is to say, large houses and no factories, the air is considerably better than in the east of London, where there are crowded neighborhoods, such as Bethnal Green, and where there are narrow streets and manufactories of different kinds. This, then, shows that we have considerable variations in the air even in one town, although that town is

certainly the largest we can take for the illustration.

Now, as air is vitiated by carbonic acid produced by combustion and by respiration, when a number of people are gathered together in a room, what becomes of the carbonic acid produced by respiration and combustion? Fortunately, the heavy gas is so acted upon that it ceases to be heavy, and rises to the ceiling, and so we have a natural means of ventilation. This I propose to show you very shortly. I have here arranged two little jars, which, I think, will show the same thing on a somewhat smaller scale. They both contain carbonic acid. That I will see first, by putting in a taper, when they both extinguish it. I will put them under precisely the same conditions, except that I will warm the gas in one jar, and to do that I will put in a little flask containing water, the water in one being hot and in the other cold. After a few minutes I will test them again with the taper, and see whether they are in the same state. While that is in operation, I will show you what becomes of the gas and the vapor produced by an ordinary fire or burning gas. That is easily done by confining the gas produced by the combustion of a large gas burner in an air balloon, and the balloon will soon be inflated and rise to the ceiling, showing the course the burnt gas would take. It is evident that the gas rises to the ceiling. We have there one natural kind of ventilation. Now I will show you with the tapers whether these two jars of carbonic acid are in the same state as they were at first. The taper is put out in one, but in the other it still burns as brightly as it would in the open air; the carbonic gas warmed by the flask of hot water has made its escape.

The next fact I want to show is that if air has once been drawn into the lungs and ejected, it is useless for either respiration or combustion. I can show it is useless for combustion, and you must take my word for it that it is not fit to breathe. If I extract the air from this jar and then return it from my lungs into the jar again I shall be able to test it with the taper, and to see whether it will furnish the taper with sufficient oxygen to cause it to burn. You see the taper is extinguished, all the oxygen of the air has not been taken out, as I will show you directly. The amount of carbonic acid in the expired breath is about 5 per cent. I have a little phosphorus here in a spoon, and as phosphorus is much more combustible than gas or a taper which will burn with less oxygen, therefore, if there is still any oxygen here I shall be able to burn it in the jar —it does not burn quite so brightly as it did in the open air, but it still burns.

The next experiment is to show the deterioration of the air by means of combustion; in the same way if the taper be burnt in the air, and be allowed to burn so as to consume so much oxygen that there is none left, it goes out. But by a little arrangement I can show you that there is still oxygen in the air, that it does not consume it all. There is the taper burning in the jar, and I will close the bottom, and make it air-tight by a drop of water. This wire passing into the jar is getting hot, so that I may be able to touch a piece of phosphorus in the centre. As soon as the taper goes out, I shall by that means be able to kindle the phosphorus, and show that all the oxygen in the jar has not been used up. Now, you see, the taper has gone out, but still that there is oxygen there is shown by the combustion of the phosphorus. The first effect, then, of respiration and combustion on the air is to render it unfit for respiration again, and unfit for combustion. We already see that the carbonic acid produced by combustion and also by respiration to a certain extent being heated, rises to the upper part of a building; and there are other means yet, besides this lightening of the heavy carbonic acid gas which causes fresh air to be introduced into a house. Some experiments made by Fedderson, of Leipsic, show that when there are two atmospheres in two different states, one hot and the other cold, there is between these a porous medium for the passage of the gas from the cold to the hot side. So that it comes to this, if we take a tube and put a porous plug in the centre, and make one side hot, leaving the other side cold, the gas passes from the cold side to the hot side. This is found to take place in houses, where there is a passage of gas through the walls of the building. Before I allude to this point further, I will just give

you an illustration or two of ventilation caused by the rising of the heated air. In every room where there is a chimney there is a source of fresh air, not down the chimney, but through the cracks in the windows and doors, and by the constant opening of doors, and thus fresh air thus entering drives forward the heated air, which has a tendency to rise, and drives it up the chimney. If we have no chimney in the room then this source of fresh air is practically valueless, because there is no escape for the vitiated air; and this may be illustrated by the jar which I have here with two candles. There is an entrance for the air below by cracks, the jar being raised 1–16th of an inch above the glass plate. The opening at the top is like the chimney in a room, the fire-place is below, the opening of the chimney is below here, and the taper burns steadily below the chimney. Here is a taper burning above what may be called the fire-place of the chimney, and as the vitiated air rises to the upper part in the bell-jar, it will in course of time vitiate the upper atmosphere, and so cease to support combustion, while the lower taper continues to burn as brightly as ever. That is already manifest here; the upper taper is languishing, while the lower one is burning brightly. Now it is out, the lower one burning as brilliantly as at first. Supposing we have a condition of things where we have no chimney, where the source of contamination is down below, such as we have in a coal mine, we must have fresh air entering somehow or other; if it cannot enter from below, it must enter from above. That it does enter from above is shown here, where I have what may be represented as a cellar or coal mine, this one tube representing the chimney of the cellar, and the other tube a staircase into it, or representing the up-cast and down-cast of a mine. That there is a draft down one chimney and up the other may be shown by the smoke traveling down the left-hand and out of the chimney where the light is. By stopping the down-shaft we may extinguish the light—the light is extinguished by reason of the want of air. That illustrates the ventilation of mines; and here is an apparatus which illustrates it much better, because this represents more nearly what is the actual state of things. A bell-jar with a chimney at the top, in other words a mine with a short shaft, is closed at the bottom so as to make it air-tight, with a little water, and after a time you will see the taper will by no means burn very brilliantly. It is not necessary for fresh air to go down a separate shaft into a mine or cellar, but it may go down the same shaft by which the foul air escapes; but, in order to effect that, if the air is perfectly still, the shaft must be divided, and that I propose to do as soon as the taper begins to languish. I will then introduce a division, which will cause the fresh air to enter down one side and the foul air to escape by the other. The taper is now beginning to die out; by interposing that division I shall cause it to revive. It takes a little time for the currents to establish themselves. Now, with a piece of brown paper, which gives me a supply of smoke, I will now find out which is the down-shaft and which is the up—down which side the fresh air is entering and which side the foul air is escaping. We have here very plainly shown the action of currents produced by the heating of the gases.

Now, the next part of the subject, the ventilation of a house by means of the passage of air through the walls, can be shown in an exaggerated form by the passage of hydrogen through a porous material. This is not to be considered by any means what takes place in a house, that is to say, we have not the passage of hydrogen, but we have a passage of cold air through the walls of a room into the house, and this experiment is made with hydrogen simply, because it is more easily shown to you than by any other means. Here is a porous vessel which may be taken roughly to represent the wall of a house, and if I bring this jar of hydrogen gas over the porous vessel, you will notice the passage of the gas through the porous vessel causes a pressure into this vessel, which ejects a stream of liquid. It has been proved, by experiment, by Pettenkofer, of Munich, that the passage of air through the wall of a house is very considerable. He examined the walls of an ordinary room in his own house, and found the change of air through the brick walls in a room, the

cubic contents of which were 2,650 feet, when the difference between outside and inside amounted to 34° F., amounted to this:

	Cubic feet.
	2,650
With a fire	3,320
All crevices stopped	1,060
With a difference of 7° Fah	780
Window open 8 feet square	1,060

This illustrates what takes place in winter, when one's repugnance to cold air causes one to shut the doors and windows and have a roaring fire. The air which cannot get in by crevices or by doors makes its way through the walls, that is to say, the doors and windows being shut, a certain increased amount of air passes through the walls into the room. What is the advantage of this? It is this, that we are supplied then with fresh air free from draft. Ventilation is not supplying fresh air, but supplying it free from draft, and this natural source of ventilation gives us really true ventilation. The amount of carbonic acid in the air may be taken on an average as about 4 parts in 10,000, and in order to keep the air fresh we should not allow the pollution of the air to extend to a greater quantity than 2 parts in 10,000 over this. Therefore, the extreme of carbonic acid in the air is 6 parts in 10,000. When the amount is more than this, the air begins to be close, that is to say, we begin to feel by the nose that there is a certain pollution in the air which you cannot exactly account for. Six volumes in 10,000 is the amount of carbonic acid which is allowable, and all above this must be considered unwholesome vitiation of the atmosphere. Then, in close places, that is to say, in places which contain more than 6 volumes in 10,000, of which there are many—workshops, offices, public buildings, theatres, all contain, generally speaking, much more than this—we have an atmosphere which can be known as unwholesome simply by the nose. The nose tells us there is something in the air which ought not to be there. What is the reason of this? It is not carbonic acid, because we cannot detect carbonic acid by the nose. It is a certain amount of organic matter thrown off from the lungs, and, generally speaking, from the body in some form or other, and this organic matter rises in proportion directly with the carbonic acid. Therefore, if we measure the amount of carbonic acid in the air we measure the amount of pollution by organic matter, and by determining the carbonic acid in the air, which we can do very accurately by chemical analysis, we also determine the amount of organic matter which vitiates the air. We do not know the organic matter, but we know there is more than there should be. In buildings in which the natural ventilation is not allowed free play, and in which no extensive mechanical appliances are used to contribute fresh air, this vitiation of the atmosphere goes on to a very great extent. For a few examples of this we have the analyses made by Dr. Angus Smith, and we find by this table that in workshops he has found the air so bad that it rose as high as 30 parts in 10,000; that is to say, the carbonic acid was very nearly ten times as much as it should have been. In theatres he found it rose to 32 volumes in 10,000 of air, in mines 78·5, an enormous quantity, and the largest amount he ever found was 250 in 10,000. Here is a table giving an analyses of air in different places, made by Dr. Angus Smith. In a Chancery Court, seven feet from the ground, with the doors closed, he found the proportion was 19·35 carbonic acid to 10,000; in the same court, three feet from the floor, 20·3; in the same building with the doors open, that is to say, when the fresh air had entered, it was 5·07 and 4·5. Then in the Strand Theatre, in the gallery it was 10·1, in the boxes 11·1; in the Surrey Theatre at 12 p. m., 21·8; in the Olympic, 8·17; in the Olympic in the boxes, 10·14; in the Haymarket, 7·5, and so on. In hospitals, where great care is taken to have large free space in the room for each patient, and a supply of fresh air regularly admitted, the amount does not rise above that of the outside air. In the Queen's Ward of St. Thomas' Hospital no more than in the outside air; in Edward's Ward of the same hospital it was 5·2. These tables show the large vitiation of air taken in crowded buildings, and in the case of the low courts it was almost as bad as any. There was another case, in the Queen's Bench, in which the air is described by Dr. Angus Smith as the foulest air that he ever found above ground.

It seems that law courts were always famous for being filled with foul air. In 1796, Brahmah, the inventor of the patent locks, who was giving evidence in a Chancery suit connected with one of James Watt's patents, complained that he could not give his evidence because he was "much incapacitated by those alkalescent and morbific exhalations ever consequent on large and close assemblies," no doubt the carbonic acid and the organic matter; and he complained that the judge's attention had "become flaccid through fatigue." This is really because of the small amount of air which is allowed to each person in the building—that is to say, the small cubic space which is available for each person's use—and, furthermore, that the amount of wall space is very small compared with the production of carbonic acid in the interior of the building. In summer, when the difference between the temperature of the inside and outside of a building is small, it is quite possible in a crowded room like a ball-room for the air to be more vitiated than in winter. Therefore, in theatres in summer we may look for a greater vitiation of the atmosphere than in winter, when the difference between outside and inside temperature is much greater. Acting upon this, last year I made some experiments at the two Italian Operas, Covent Garden and Drury Lane, and from several experiments made in each case, I found the following numbers: April 28th, Covent Garden amphitheatre, amount, 22·5 in 10,000 of air, near what is called a ventilator, although the air which was admitted was not pure, it was 17·6, and near an open door it was 14·8. The people in the building were listless and gaping, and evidently wanting in attention somewhat, and did not seem to be lively and animated, and they exclaimed how delightful was the fresh air coming in from an open door, yet this fresh air contained 4·8 volumes of carbonic acid in 10,000. In Drury Lane the average of three analyses was 25·9. You must not think that because these were taken in the upper part of the house that down below there was any great difference. In a private box, for instance, the space is so enclosed that the air very often there is worse than in the gallery, especially at the back of the box. In the stalls of Covent Garden, between the acts, when the curtain is down, the air is then very hot and very impure. I have not made an analysis of that, but one can feel it when the curtain is down; the supply of fresh air is practically cut off, because the supply of fresh air comes from behind the scenes, all other entrances being carefully closed by swing doors, and there being a great want of openings to supply fresh air from the outside. There is no doubt the large amount of gas burnt in a theatre, if ventilation had free play, would considerably facilitate the entrance of pure air. We have heard great complaints about public offices, more especially the British Museum; and last summer I made some experiments on the air of an office of which great complaints had been made, namely, in the money-order office in Aldersgate Street. In one room where there were a large number of clerks, a tolerably high room, with large windows, the proportion was 22.2 and something over, in fact it reached up to 25, this being the average of two or three analyses. This is as bad as a theatre. In the same office, on another occasion, without the gas lighted, it was 17·6. In the same office, with the windows open, there were 4·2 volumes, that is to say, it was practically the outside air. This gives you a tolerable notion of the amount of carbonic acid, and consequently the amount of pollution in the air in various buildings.

Now, with regard to the amount of fresh air which is necessary for each person. This is far more considerable than you would imagine. The amount of carbonic acid given off by an average size man in an hour, from the lungs and skin, is about 7-10ths of a cubic foot, and if we take it at 6-10ths we shall be below the quantity. A good oil lamp, or a couple of good candles, will also give 6-10ths of a cubic foot. Therefore, a man in a room with a lamp or two candles, gives one and one-fifth of a cubic foot in an hour. Now I have told you before that the amount of allowable pollution in the air was 6 volumes in 10,000; beyond that the atmosphere becomes unwholesome. Therefore, in order to keep the air fresh with two men in a room, or one

with a lamp or two lighted candles, would have to require this amount of carbonic acid produced with 5,000 volumes of air. He would therefore require 6,000 cubic feet of fresh air, and one man, therefore, in occupying a bed-room for instance, would require 3,000 cubic feet for his own use. This is pure calculation. What does the experiment show? In some experiments made in Paris to determine the amount of fresh air which should be supplied to hospitals it was found, by pure experiment, not by calculation at all, that this should be from 3,120 to 2,470 cubic feet in an hour.

	Cubic feet.	
Hospitals	2,120	
" for wounded	3,530	
" for epidemics	5,300	
Workshops	2,120	
" for unhealthy trades	3,530	
Barracks, day	1,060	
" night	12,410 ..	1,765
Large rooms for long meetings	2,120	
" short "	1,060	
Schools for children	424 ..	530
" for adults	880 ..	1,060

Now, in order to get this 3,000 cubic feet of air in an hour supplied to a large audience in any public building, it is absolutely necessary, as far as I know at present, to resort to some special means of supplying fresh air, and a very good instance of that is afforded at the Royal Institution. Very great care was taken, there four or five years ago by arranging with upright cylinders going to the roof from under the gallery, in which gas-jets were burnt, and passages connected with windows which entered underneath the seats and above the heads of the audience underneath the gallery, to admit fresh air; but, nevertheless, on a night when there is a large audience at the Royal Institution the air is undoubtedly bad. It is not so much, perhaps, the contamination by the breath as by the gas and heat—it feels extremely hot. To estimate whether the place is close or the air is polluted by breath, it is necessary to enter from the outside directly. That I have not done. I have gone in at the commencement, when the audience was arriving, and remained there to the end. Still, there is no doubt people complain continually about the air in the upper part of the building being extremely bad. There is no doubt that the Royal Institution, from the very fact that such care was taken in the ventilation, is far better than other buildings of the same kind, but it shows that, in order to supply fresh air to a building crowded in that way, some mechanical means must be resorted to. Such mechanical means are, so far as I know, a rotating fan, which drives air forward through pipes and distributes it to the building, and such a rotating fan is applied in America to the ventilation of hospitals on a large scale. In summer, when the air is hot, it is passed through ice to cool it; and when in winter it is cold, it is passed over hot-water pipes to warm it; and so a regular supply of fresh air is driven into the building, and allowed to find its way out where it can. In the Stamp Office at Somerset House, which is below the level of the ground, this means is resorted to, and I should imagine, in consequence of their having such a contrivance, that the air was in such a place wholesome. In this country it is not advisable to change the air of a room more than 4 to 6 times in the course of an hour. It is therefore necessary, generally speaking, to have a sufficient supply of fresh air to begin with, in order to prevent the air being changed too rapidly, and it has been calculated, as stated by Dr. Parkes in his book on "Practical Hygiene," that from 750 to 1,000 cubic feet per head per hour is necessary. In a crowded building where mechanical ventilation could be resorted to, the air could be so warmed as to produce no feeling of draught. I may as well mention what this feeling of draught is, and why it is that diffusion through the walls is unfelt. When the air travels at a lower rate than nineteen inches per second, generally speaking, that is to say, if it is not very cold, it is unfelt. There are around us continued currents of air pouring upwards by the heat of the body, causing the air surrounding us to become warm and rise up with fresh air coming against us; still these currents we are unconscious of. It is only by an extremely delicate instrument placed under your top-coat that these currents can be detected. Then on a day when not a leaf is stirring, not a ripple on the water, there are constantly currents playing about; these are unfelt, and are produced at a rate of some-

thing less than nineteen inches per second. That this rate is unfelt may be proved by passing the hand through the air at a speed somewhat less; and, of course, passing the hand through the air is just the same as passing the air over the hand if it were stationary.

Ventilation then may be considered, generally speaking, as the passage of fresh air to an apartment at a rate of less than 19 inches per second, so as to reduce the carbonic acid in the air to 6 volumes in 10,000. Dr. Angus Smith, who has done such valuable work in the matter of air and ventilation, gives us a means whereby we can estimate whether the air of a room is wholesome or not, whether the vitiation is increased to an extent which is unwholesome, and that is a very simple test. It consists in taking a bottle, which holds 10½ oz. of air when the stopper is placed in the bottle. If I blow the air into this with the bellows, and then take ½ oz. of saturated lime-water, the test consists of this, that if there is more carbonic acid in the air of that bottle than 6 in 10,000, shaking up this ½ oz. of lime-water in it will cause the lime-water to become turbid. Trying the experiment with the air of this room it becomes just turbid, and that is all. I should not think from this experiment that there were more than 6 volumes in 10,000. It just shows the slightest trace of turbidity and that is all. By taking a smaller bottle and the same amount of lime-water the amount of carbonic acid in the air may be told to the extent of one volume in 10,000, and by means of a flexible bottle and the lime-water contained in another apparatus, we may determine the amount with some degree of accuracy.

I will pass over the determination of the carbonic acid in the air, and I will go to another matter, a very important one, which is the carbonic acid in the soil. Pettenkofer has shown that if we take a gravelly soil, cut a piece out, and measure the amount of water that we can pour into it, the amount of water it will take up will amount to one-third the space occupied by the soil. Therefore, the soil consists of one-third of air. Now Boussingault has shown that the amount of carbonic acid in the air contained in the soil was very much more than that contained in the air of the atmosphere. He found that in a field recently manured it amounted to 221 parts in 10,000 of air, and in another field 974, and in a field of carrots 98, a vineyard 96, forest land 86, loamy subsoil 82, sandy subsoil 24, garden soil 36, prairie 179. You see then that what may be called the ground-air is highly charged with carbonic acid. When we warm a house by a fire it creates an upward draught, and undoubtedly the air from the soil passes into the house. If you doubt this, a very good case to prove it is the one Pettenkofer mentions at Munich of a house in which there was no gas laid on or any gas pipe within twenty yards of the house, yet the people in the house were poisoned by an escape of gas. This escape from the main traveled through the earth and gained admission to the house. Nearer home there has occurred a case of a still more striking character at Southgate, Colney Hatch, where one or two small houses were completely wrecked in November last by an explosion of gas. This gas was not laid on to the houses at all, the main passed through the street, the houses stood back from the street some distance; the main was cracked, the gas traveled through the soil, gained admission to the house, it smelt for several days, and finally exploded one evening on a lamp being lighted, and completely wrecked the building. Here, then, is striking evidence of gas passing through the soil. What does this teach? It teaches that the air of the soil should be as far as possible prevented from being polluted. If the soil is polluted by a leaky drain pipe we have that communicated to the soil which, if it gains admission to the house, may lead to disastrous results, the breaking out of typhoid fever, and those other diseases which are always traceable to contaminated air and water, which are familiar to every one. It is therefore highly important that this matter should have attention called to it. It is not at all an unusual thing in the neighborhood of London for speculating builders to build houses and make drain-pipes which have no outlet; they put drain-pipes below the house, which lead nowhere; the consequence is, that after the house is let the unfortunate tenant is perfectly ignorant of the fact

that everything which escapes by the drain-pipes is lodged in the earth. Of course, after a time, this cannot fail to be found out, but frequently only when it is too late.

Having mentioned this matter, I think I must now conclude my paper, and I hope sincerely that I may succeed in drawing attention to these matters which are undoubtedly of the highest importance. In preparing my experiments, I have to give my best thanks to my friend, Mr. Thomson, who undertook the trouble for me this afternoon, otherwise I do not think I could have performed them.

RAILWAY GAUGES.

From "Engineering."

Under the title of "Some Notes on the Early History of the Railway Gauge," Dr. William Pole has lately read a paper in which he strongly attacks the reaction towards narrow gauges now being so strongly shown in all countries where cheap railways are a necessity, and he goes so far as to state his belief that "the late official Indian narrow gauge movement will be pointed to by posterity as a blot on the mechanical character of the British nation. It will not only show, as Oxenstiern said, 'with how little wisdom the world is governed,' but it will serve as an illustration, added to many others, of how, in spite of the general spread of scientific knowledge, the most incomprehensible delusions may prevail." Further, Dr. Pole, after speaking of the introduction of the broad gauge, by Brunel, says: "Would any one, with this history before him, believe that a great economical policy had been based on the uneconomical proposal to push the wheels closer together under a carriage body? Yet the records of the past few years show that this has actually been done. It is said that a narrow gauge is cheaper; but this argues simply a misunderstanding of what gauge means, and what significance it has in railway construction." These are forcible opinions, and coming from an engineer of Dr. Pole's position, they merit a reply, notwithstanding that the errors they include have been fully shown by the results of practical experience.

We have no intention of discussing the historical portion of Dr. Pole's paper, but in order to explain the matter more clearly it would be necessary to state briefly the steps by which Dr. Pole arrives at the conclusions we have quoted. The 4 ft. 8½ in. gauge Dr. Pole states to have been adopted from the accidental circumstance of the Northumberland colliery lines being made to that gauge, and he goes on to remark that in the earlier rolling stock all the bodies were situated between the wheels, and that it was not until the traffic had been somewhat developed on the Liverpool and Manchester Railway that bodies extending over the wheels and axles with outside bearings came into use. This form of vehicle Dr. Pole characterizes as an "abnormal type," and "inherently defective in a mechanical point of view, and differing essentially from that which the experience of the world in all preceding ages had established as the proper one for wheel carriages." According to Dr. Pole, in fact, things were in a very bad state when Brunel stepped in to revolutionize matters by introducing the broad gauge. Brunel, he asserts, intended to place the bodies of his carriages between the wheels and to make the latter of larger diameter than usual with a view of diminishing friction, and under these circumstances the width of the gauge was determined so as to allow of placing between the wheels a private carriage, which was the broadest article ordinarily requiring to be transported by rail. As a matter of fact, however, the construction of carriages which Dr. Pole terms an "abnormal type" was, except in some of the earlier vehicles, adopted on the Great Western as on other lines, and the history of this point is judiciously referred to in the paper under notice, as "somewhat obscure." Dr. Pole, however, adheres to his proposition that the ordi-

nary type of railway carriage with outside bearings is mechanically wrong, that narrow gauge railways are a mistake, and that the gradual disappearance of Brunel's gauge, which he so highly commends, has been brought about not by any inherent defects in the gauge itself but simply from the evils of break of gauge which the Great Western Company had to suffer. On these points we propose to have something to say.

In the first place, as regards the construction of railway vehicles which Dr. Pole calls "abnormal," we entirely disagree from the conclusions at which he arrives. More than four years ago, in dealing with the stability of rolling stock (*vide* vol. x., page 439), we showed that when vehicles are "carried on bearings situated inside the wheels, the resistance to the overturning of the upper part of the vehicle on the springs is always less than that opposed to the overturning of the whole vehicle on the rails," and it thus follows that if the type which Dr. Pole so admires be adopted, the full stability due to the width of the gauge cannot be obtained. It also follows, as a collateral deduction from the above fact, that with inside bearings the springs used must be much stiffer than with outside bearings, to maintain the same control of the oscillations of the body, and that hence the outside bearings afford the means of producing a more easily riding carriage. Under the ordinary arrangement, too, the bearings need be made only about two-thirds of the diameter which would be necessary were they placed inside the wheels, and this, of course, proportionately reduces the axle friction. A third advantage is that by extending the body of the wagon or carriage beyond the wheels, a vehicle can be constructed having a less proportion of dead weight to paying load, than if the body was kept between the wheels, while the former mode of construction also enables a greater number of passengers to be carried per foot-length of train, and thus enables an economy to be effected in length of platforms at stations, etc. Altogether theory, as well as practice, points to the ordinary type of railway vehicle as being advantageous rather than "abnormal," while we are unaware of a single point of real superiority possessed by the type which Dr. Pole so strongly advocates.

We now come to the question as to the advantages of the narrow gauge lines which are now being so extensively built in almost every part of the world where railways are known. Respecting these lines our opinions are—as our readers scarcely need to be reminded—diametrically opposed to Dr. Pole's, and we have on many occasions entered into the matter so fully that it will only be necessary for us to speak concerning the salient points here. Dr. Pole insists that so long as the rolling stock is made to suit a given traffic the width of the gauge can make no material difference in the cost of the line, for he says, "the cost of the permanent way must depend upon the weight to be carried, while that of the overworks can only be governed by the dimensions of the loaded vehicles, into neither of which elements does the gauge necessarily enter." That he should insist upon such a statement as this is, we think, a remarkable exemplification of his own words already quoted, "how, in spite of the general spread of scientific knowledge, the most incomprehensible delusions may prevail." We should have thought that everybody conversant with railway construction and working was aware that the fact of a given traffic having to be accommodated by no means at once fixes the best proportions of the rolling stock to be employed. The proportions, in fact, are to a large extent dependent on the gauge, and are not, as Dr. Pole appears to suppose, dominant over the latter. It is quite true that in some intances the fact of certain articles having to be transported may fix the minimum width of vehicle admissible, but in all ordinary cases the width thus demanded is well within that which can be provided on such narrow gauge lines as we advocated, and such as are being made in India, so that this point does not enter into the discussion. As far as general merchandise is concerned the proportions of the vehicle used for conveying it can be varied within wide limits without introducing any practical inconveniences. It thus by no means follows, as Dr. Pole appears to suppose, that to accommodate a given traffic, the vehicles will, or ought to be, made of a certain width, whatever the width of

the gauge may be. On the contrary, it will be found that for every gauge there is a certain width of vehicle which gives the most beneficial results as regards proportion of dead weight to paying load, and necessarily this width becomes less as the gauge is reduced. This being so, Dr. Pole's assertions about the cost of permanent way and overworks at once fall to the ground, for the narrower the rolling stock the less is the weight per foot of train, and hence the less is the strain thrown upon the permanent way, while, of course, with a reduced width of wagons the less can be the span of the over-bridges. In other words, the adoption of a narrow gauge enables a certain weight of train to be distributed over a greater length of line than would be possible with a wider gauge, unless in the latter instance vehicles of a type which may be justly characterized as "abnormal" were employed.

Dr. Pole absolutely ignores the facilities which narrow gauge lines afford for economical management and working. Yet these matters are quite as important as the reduction of first cost. A reduction of the gauge is accompanied by a reduction in the size of vehicle which can be most profitably employed, and hence narrow guage rolling stock is not only more frequently run with full loads than the stock on a wider gauge could be, but the vehicles, whether loaded or unloaded, are more easily handled at stations, and thus a source of economy is introduced, which all who have had to do with railway management can well appreciate. As we have pointed out on former occasions, in fact, the lightness and handiness of narrow gauge stock leads to numerous sources of economy which it is impossible to enumerate here, but which should by this time be well understood by all who have studied the question.

Perhaps, however, the best answer to Dr. Pole's assertions respecting the policy adopted by the Indian Government regarding their new lines, is to be found in the every-day experience now being gained with narrow gauge railways. Everywhere almost we find such lines spreading. In the United States upwards of 2,000 miles of such lines have already been laid, while in Canada, South America, and our Australian colonies, narrow gauge railways have taken deep root. Nearer home, too, we find such lines constructed and in course of construction, in France, Germany, Italy, Russia, Norway, and Switzerland, and everywhere we hear good accounts of the results obtained from them. In a paper on the Rigi Railway, read before the Institution of Civil Engineers in 1873, Dr. Pole remarked that, although the railway in question "is in every respect a special and exceptional line, and intended for the very lightest character of traffic, the Swiss with their usual good practical sense have avoided the foolish fallacy of narrowing the gauge;" it, may, however, interest Dr. Pole to know that the Swiss "with their usual good practical sense" are not only now building metre gauge lines, but are also contemplating the introduction of narrow gauge tramways. The fact is that with very few exceptions narrow gauge lines have one great source of attraction denied to many of their more pretentious brethren. *They pay.*

It was at one time considered that it would be impossible for narrow gauge lines to provide the engine power necessary for carrying heavy loads or for working steep gradients. This, however, has now long been proved to be entirely a fallacy, the Fairlie system affording the means of placing, on even the narrowest lines, really powerful locomotives. Thus the Festinoig Railway of 1 ft. 11½ in. gauge has now a Fairlie engine with 730 square feet of heating surface, while Mr. Fairlie has built engines with 829 square feet of surface, for the Patillos Railway, Peru, a line of 2 ft. 6 in. gauge, and others with 1,325 square feet of surface for the 3 ft. 6 in. Livny Railway, Russia. We have merely mentioned these out of numerous examples of narrow gauge Fairlie engines to show the capabilities of the system as already proved; but we may add that none of these examples represent the most that can be done on the respective gauges. If required, Mr. Fairlie would no doubt undertake the construction of still more powerful locomotives, and we may in fact say that the capabilities of the narrow gauge are now practically not in any way limited by the question of engine power. As we have frequently

pointed out, too, the Fairlie system and narrow gauge lines are intimately associated in several ways, for not only does the Fairlie system enable an engine power to be provided to an extent almost unattainable in any other way, but it also enables engines to be constructed which are eminently adapted for traversing the sharp curves generally to be met with on railways where first cost is an important consideration. This system of locomotive in fact enables the capabilities of narrow gauge railways to be fully developed, and we are glad to find that this fact is now being daily recognized, and that the advantage of narrow gauge are being appreciated by those who formerly regarded it as of very limited application, but who, throwing aside prejudice, have by further inquiry made themselves acquainted with the real truth of the case. In this number Dr. Pole does not at present appear to be included.

RAILWAY ACCIDENTS.

By FRED. CHAS. DANVERS, C. E.

From "Quarterly Journal of Science."

So much attention has of late been given to the subject of railway accidents, and the best means of preventing them, and so important is it in the interest of the public generally, that a few pages of the "Quarterly Journal of Science" may, with advantage, be devoted to a consideration of how far all known and practicable means for the mitigation of the dangers of railway traveling have been adopted. In investigating this question we must refer briefly, in the first instance, to the early history of railway legislation, with a view to trace what steps have been taken by the Government for the protection of travelers, prior to enquiry as to what action had been taken by the railway companies themselves with the same object.

The earliest railway or tramway Act was passed in 1801, for the construction of a railway from Wandsworth to Croydon, for "the advantage of conveying coals, corn, and all goods and merchandise to and from the metropolis and other places." From this period new tramways or railways were sanctioned in almost every session. The Acts by which the earlier railway companies were established followed very closely, in their general scope, the provisions which had been applied to canal companies. The promoters of the project were constituted a corporation, and were authorized to raise such money, either by shares or by borrowing, as they required for completing their undertaking; and they were empowered in their corporate capacity to take lands compulsorily, and to charge tolls at their discretion for the use of their railway, within the limits of certain prescribed rates, for various classes of goods. In the Act for the Liverpool and Manchester Railway, passed in the year 1825, and in other subsequent similar Acts, a further provision was introduced, that if the dividends should exceed 10 per cent. an abatement should be made from the maximum tonnage rates of 5 per cent. on the amount thereof for each 1 per cent., which the Company might divide over and above a dividend of 10 per cent. on its capital. In their capacity as owners of a road, railway companies were not intended by Parliament to have any monopoly or preferential use of the means of communication on their lines of railway; on the contrary, provision was made, in all or most of the Acts of Incorporation, to enable all persons to use the road on payment of certain tolls to the company, under such regulations as the company might make to secure the proper and convenient use of the railway. But no sooner were railways worked on a large scale with locomotive power than it was found impracticable for the public in general to use the lines, either with carriages or locomotive engines; and the railway companies, in order to make their undertakings remunerative, were compelled, with the

assistance of the persons who had been previously engaged in the carrying trade of the country, to embark in the business of common carriers on their lines of railway, and conduct the whole operation themselves.

In consequence of the increasing number of Railway Bills annually coming before Parliament, and the necessity of securing consistency in private bill legislation, the House of Commons, in 1837, appointed a select committee, to which were referred all petitions for private bills, and it was the duty of this committee to decide how far the standing orders had been complied with in each case.

In 1840, another Select Committee of the House of Commons, appointed to report on the railway system, came to the conclusion that the right secured to the public by the Railway Acts, of running their engines and carriages on the railways, was practically a dead letter. In consequence of their recommendation that the executive government should be entrusted with the duty of inspecting new lines of railway, and of exercising a general supervision over the manner in which the railway companies used their powers, an Act was passed by which it was provided that no new railway for the conveyance of goods or passengers should be opened without previous notice to the Board of Trade, and the Board were empowered to appoint officers to inspect all new railways. The Board was also empowered to require, under a penalty, that every railway company should deliver to them returns, in whatever form they might prescribe, of the traffic in passengers and goods, as well as of accidents attended with personal injury, and a table of tolls and rates from time to time levied on passengers and goods. All by-laws already made by companies were to be certified to the Board, and no new ones were to be made without its sanction. The Board was also constituted the guardian of the public interests, being empowered at its discretion to certify to the law officers of the Crown any infraction of the law, and the law officers of the Crown were thereupon required to take the requisite legal proceedings. The power which had been conferred upon proprietors of and adjoining railways by their private Acts of Parliament, for making junctions, was placed under the control of the Board of Trade, with a discretion to regulate the manner in which it should be exercised.

In 1842, the returns of the accidents required to be made to the Board of Trade were extended to all cases, whether or not they were attended with personal injury; and in 1844 parliamentary trains were established by law, and the powers of the Board of Trade to compel railway companies to comply with the law were extended to all unauthorized proceedings on the part of the railway companies. In 1846 an Act was passed establishing a Board of Commissioners of Railways, to whom the powers possessed by the Board of Trade were transferred; but in 1851 the Board of Commissioners was abolished, and its powers and duties were re-transferred to the Board of Trade.

In 1857 a Select Committee on Accidents on Railways was appointed, who in their Report of the 25th June, 1858, classified the causes of accidents under the three following heads: Inattention of Servants; Defective Material, either in the works or rolling stock; and Excessive Speed. Much stress was laid by the Committee on the necessity for punctuality in the departure and arrival of trains; they considered that it should be imperative on every railway company to establish a means of communication between guards and engine-drivers, and that a system of telegraphic communication on the lines should be enforced, in order that they might be worked on the block system; and they concluded by recommending that, with respect to signals, breaks, and other precautions, such details should be left to the management of the railway boards, but that the Board of Trade should be invested with further powers to enable them the more effectually to control the working of railways with a view to diminishing the number of railway accidents.

Bills have at various times been introduced with the object of compelling railway companies to adopt some precise system of working, but they were not passed; and in 1866, in a bill of this nature, it was for the first time proposed to compel railway companies to

adopt a means of communication between passengers and guards, and between guards and engine-drivers of all trains. This Bill, however, did not, at the time, become a law, but was withdrawn.

In 1865 a Royal Commission was appointed to enquire generally into the subject of railways, and to report, amongst other matters, whether, with a due regard to the progressive extension of the railway system, it would be practicable by means of any changes in the laws relating to railways, "more effectually to provide for securing the safe, expeditious, punctual, and cheap transit of passengers and merchandise upon the said railways."

Up to this date the legislation upon railways directed that no line should be opened until it had first been approved and passed by the Board of Trade Inspectors, but after it had been once opened for traffic the manner of working was left entirely in the hands of the railway company, power being, however, reserved to the Board of Trade to cause the railways, the engines, and the carriages to be inspected by their officers whenever they might think fit, and they might, when applied to, make regulations for the safe working of the traffic at the junction of the lines of two companies. The railway company, in undertaking the duty of carriers, became liable under the common law to compensate persons injured, and under Lord Campbell's Act to compensate the relatives of persons killed by the company's negligence or by that of their servants. Thus Parliament relied upon the principle of leaving the responsibility of the safe working of railways with the companies rather than upon giving the Board of Trade the power and duty of interfering in the details of management.

The Royal Commission of 1865, in their Report, expressed the opinion that the plan of relying for the safe working of railways upon the efficiency of the common law and of Lord Campbell's Act, had been more conducive to the protection of the public than if the Board of Trade had been empowered to interfere in the detailed arrangements for working the traffic. They recommended, however, that, on the one hand, railway companies should be absolutely responsible for all injuries arising in the conveyance of passengers, except those due to their own negligence; and that, on the other hand, the liability of the railway companies be limited within a maximum amount of compensation for each class of fares; but that any passenger should be entitled to require from the company any additional amount of insurance he might desire, on paying for it according to a fixed tariff. They also recommended that claims for compensation should not be admitted unless made within a certain period, and that the railway companies should have the right of medical examination of the claimant; and, further, that to the power already possessed by the Board of Trade of appointing officers to inspect railways and rolling stock, should be added a power for the inspecting officer to require the attendance of the officers and servants of the company as witnesses, and the production of books and documents bearing on enquiries directed by the Board of Trade; and that the reports of the inspecting officers on accidents should be made public.

In 1870 a Select Committee of the House of Commons was appointed to enquire into the law and the administration of the law of compensation for accidents as applied to railway companies, and also to enquire whether any, and what, precautions ought to be adopted by railway companies with a view to prevent accidents. On the second point the Committee pointed out that on those lines where the block system had been adopted it had materially conduced to the safety of the public, and they recommended the evidence collected by them on this subject, as well as that in favor of the principle of the interlocking of signals and points, and concerning continuous breaks, to the careful consideration of railway boards of directors.

Last year (1873) a Bill was introduced into Parliament for the "Regulation of Railways," with a view to the prevention of accidents. This Bill had for its object the enforcing upon all railway companies the obligation of securing an interval of space between trains following each other on the same line of rails, which is now generally effected by what is known as the block system, and it further proposed to enforce the interlocking sys-

tem. A Select Committee was appointed by the House of Lords to consider this Bill, but whilst strongly recommending the adoption of both the block system and the interlocking system on all important lines of railway, yet, relying on the great exertions recently and very generally made by different railway companies to extend both systems, and other great improvements now in progress, the Committee recommended that the Bill should not then be proceeded with. They recommended, however, that the Board of Trade should call for such information as might enable the inspectors, in their annual reports, to state specially the progress made in their adoption on all passenger lines, after which, it was considered, Parliament would be in a condition to decide whether or not it would be right to require the further and more prompt extension of these systems on those lines where they might still be necessary.

Another Commission is at the present time occupied in considering how railway accidents may best be prevented, and what legislation, if any, is desirable on the subject in the interests of the public at large. It will be observed that, hitherto, the action of Parliament has been rather to recommend and advise than to pass coercive measurers to compel railway companies to adopt improved means for the protection of their passengers. At the same time, additional powers have been vested in the Board of Trade from time to time for the more efficient inspection of lines open to the public, and there can be no doubt that the duties devolving upon that branch of public service have hitherto been conducted satisfactorily in the general interests, but it is hardly to be supposed that its action should meet with universal approbation, or, indeed, that it should be always free from blame. It is very obvious that the officers of the Board of Trade are not in good odor with the present President of the Institution of Civil Engineers; and, as his observations may probably be taken to represent the feelings of railway officials generally towards them, we quote the following remarks made by him in his inaugural address on the 13th of January last:

"There is also a 'popular delusion' which I think ought to be corrected. The public believe that the various recommendations made to the railway companies from time to time by the officers of the Board of Trade, such as the block system, interlocking of points, &c., are really inventions of those officers, whereas the fact is that not one of these systems or inventions, or any new idea in connection with the workings of railways, has ever really been suggested by them.

"The railway companies also are at a great disadvantage with the public in respect to the reports which are from time to time made by the Government inspecting officers—their dictum is never questioned by the public; and although railway officers of great experience constantly differ from those officials in the conclusions at which they arrive, the railway companies feel that any appeal against these reports is useless, and practically judgment is allowed to go by default.

"In making their reports, the officers of the Board of Trade are in the position of *ex post facto* judges, and I need hardly point out that there is a great difference, to use an expression of our late President, Mr. Hawksley, between looking into the events of the week that is past, and looking into middle of next week; and should the country at any time become the purchasers of the railways, these officers will soon find the difference in their position when the responsibility of working the lines devolves upon them.

"Captain Tyler, in his valuable Report on Railway Accidents in 1872, says: 'Whatever be the amount of care taken, the item of human fallibility will still remain, and will always be the cause of a certain number of accidents.' And he states that in 180 cases of accidents out of 238, 'negligence, want of care, or mistakes of officers, were apparent.'

"This is a subject to which for years past I have devoted a great deal of attention and anxious thought, and I attach much more importance to the item of 'human fallibility' than Captain Tyler appears to do."

To these remarks Captain Tyler replied as follows, in a paper read by him before the Society of Arts in May last:

"When Mr. Harrison attributes to the author that he does not sufficiently appreciate the element of human frailty as contributing to accidents on railways,

and leaves it to be understood that improved arrangements will not materially lessen the number of accidents and their serious results, the author would venture to reply that he estimates that cause of accident at no more and no less than has actually been found by experience of many years to attach to it."

This subject also was referred to by the Select Committee of the House of Lords, who, in their report of last year, remarked:

"It may be confidently stated that the general safety of railway traveling would be increased by the more extensive employment of the block and of the interlocking systems. Some witnesses stated that these precautionary arrangements and mechanical appliances tend to lessen the sense of responsibility in the engine drivers. Such an effect may have been produced, but, nevertheless, the advantages resulting from the introduction of these systems are practically admitted by all the witnesses, and, in the judgment of the Committee, decidedly preponderate."

We do not propose to follow up this subject further at present, beyond remarking that, whilst fully admitting the element of human frailty, which must exist wherever the hand of man is engaged, we entirely concur in the conclusion arrived at by the Select Committee of the House of Lords, that the introduction of improved machanical contrivances for the more efficient and safe working of railways is likely to overbalance in its advantages the evils likely to arise from the element of "human frailty," which must be, at all times, inseparable from their introduction.

The next subjects for consideration are the extent to which railway passengers are liable to accidents, and how far former risks are increased or diminished in proportion to the number of travelers, and to the adoption of means with a view to their prevention. A general review of the number of fatal accidents to passengers from all causes beyond their own control, between the years 1847 and 1873 inclusive, is contained in Captain Tyler's General Report to the Board of Trade on the accidents which have occurred on the railways of the United Kingdom during the year 1873, from which the following extract is taken:

"The total number of persons recorded at the Board of Trade as having been killed on railways during the year was 1372, and the number of injured was 3110. Of these, 160 persons killed, and 1750 persons injured, were passengers; and the remainder, 1212 killed and 1360 injured, were officials or servants of the railway companies, or trespassers, or others who met with accidents at level crossings, or from miscellaneous causes. Of the passengers, 40 were killed, and 1522 were injured, from causes beyond their own control. The total number of passenger-journeys having been 455,272,000, it follows that the proportion of passengers killed was, in round numbers, 1 to 2,845,450, and of passengers injured 1 to 260,155; and that the proportions of passengers killed and injured from causes beyond their own control were respectively, 1 in 11,381,800, and 1 in 299,127. This was a decrease on the average of the number killed, and an increase of the number injured, from causes beyond their own control, in the previous three years, in which the proportions were 1 to 11,123,931 killed, and 1 to 357,000 injured. Of the officers and servants of railway companies there, have during the past year, in proportion to the total number employed, as nearly as they can be estimated (say 250,000), been killed from all causes 1 out of 323, and injured 1 out of 213; but accidents to servants do not appear, in many cases, even now to have been reported by certain of the railway companies, and their numbers would, if the whole truth could be ascertained, be considerably increased.

"The following statement shows the proportion of passengers killed to passenger-journeys for the three years ending 1849, the four years ending 1859, the four years ending 1869, and the four years 1870, 1871, 1872, and 1873, respectively: (*See table next page.*)

From these figures it appears that the average of fatal accidents for the last four years was higher than in the similar cycle immediately preceding; and the conclusion that would naturally be formed at first thought is, that a maximum of safety in railway traveling has been arrived at. On a closer examination, however, it does not in any way seem that this is the case. No doubt traffic

Year.	Number of passengers killed from all causes beyond their own control.	Number of passenger-journeys exclusive of journeys by season-ticket holders.	Proportion killed to number carried.	
1847 1848 1849	36	173,158,772	1 in 4,782,188	
1856 1857 1858 1859	64	557,338,326	1 in 8,708,411	
1866 1867 1868 1869	91	1,177,646,573	1 in 12,941,170	
1870	66	336,545,399	1 in 5,099,172	Average of these 3 years, 1 in 11,123,931.
1871	12	375,220,754	1 in 31,268,396	
1872	24	423,874,822	1 in 17,619,784	
1873	40*	455,272,000	1 in 11,381,800	

has increased on may lines in a more rapid ratio than the development of increased accommodation for such traffic. But the accidents in 1870 were considerably in excess of the proportion given in the above table since 1856; but if we omit that bad year, and take only the average of the last three years, it will be seen that the number of passengers killed from all causes beyond their own control was only 1 in 20,089,993, which shows a considerable improvement upon any of the earlier periods referred to. The year 1871 was, it appears, exceptionally free from fatal accidents; but Captain Tyler shows that it is not desirable to lay too much stress on the results of working in the case of any particular year, either as to the number of sufferers or as to the number of accidents. More returns of accidents than formerly have been rendered by the companies within the last two years. Inquiries have also been instituted during those two years into a greater proportion of cases, and there is, humanly speaking, much of chance in both. A dangerous or defective mode of working is frequently carried on for a great length of time without bad results, while there are accidents and loss of life where greater precautions have been adopted, or less risk is apparently incurred. A comparatively trifling defect may in one case lead to much loss of life, whilst important defects may, in another case, be unattended with accident.

Setting aside considerations of humanity, the railway companies have a positive and direct pecuniary interest in the avoidance of accidents, and capital laid out with that object in view is not likely to be wholly unproductive. Under Lord Campbell's Act the railway companies are pecuniarily liable to those to whom any injury is caused by accidents, &c., on their lines, and, during the ten years from 1848 to 1857 inclusive, there was paid as compensation on account of passengers and goods injured on fourteen lines of railway, no less a sum than £414,440, or at the rate of over £40,000 a year. For the five years ending with the year 1871, there was similarly paid £2,348,568, of which £1,622,370 was as compensation for personal injury, and £726,198 as compensation for damage to goods. These sums do not, however, include anything on account of injury to the servants of the railway companies, to whom the latter are not liable by law in the same way that they are towards their passengers or goods traffic.

The following table shows the number of train accidents that have formed the subject of inquiry, and have been reported on, by officers of the Board of Trade, during the past four years. The number of cases inquired into during the preceding five years averaged 83 per annum, upon which those for the year 1870 show an increase of 57 per cent:

* The deaths of two of this number were not the results of train accidents.

1870.	1871.	1872.	1873.	CAUSE OF ACCIDENT.
9	19	21	24	From engines or vehicles meeting with, or leaving the rails in consequence of obstructions, or from defects in connection with the permanent way or works.
10	22	17	23	From boiler explosions, failures of axles, wheels, tyres, or from other defects in the rolling stock.
61	9	22	18	From collisions between engines and trains following one another on the same line of rails, excepting at junctions, stations, or sidings.
	63	91	98	From colisions within fixed signals at stations, or sidings, &c.
18	19	32	20	From collisions at junctions.
3	2	5	3	From collisions between trains, &c., meeting in opposite directions.
1	—	—	3	From collisions at level crossings of two railroads.
14	12	34	36	From passenger-trains being wrongly turned or run into sidings, or otherwise through facing points.
—	2	7	5	From trains entering stations at too great speed.
6	11	9	11	On inclines.
9	12	8	6	Miscellaneous.
131	171	246	247	

An examination of this table will show that the more serious classes of accidents are evidently upon the increase, more particularly from collisions within fixed signals at stations or sidings, and from passenger trains being wrongly turned, or run into sidings, or otherwise through facing points. But it must be observed that the accidents are in no respect proportionate to either the length of, or the amount of traffic on, any particular line of railway, some lines being particularly unfortunate in this respect, while others enjoy comparative immunity from accidents. Increase of traffice, high speed, and variations of speed, tend materially to increased risk, to greater numbers of accidents, and to more severe accidents when there is insufficient accommodation in lines and sidings, when signal and point arrangements are defective, when the means of securing intervals between the trains are defective, without sufficient break-power, without good construction and high maintenance, and when the appliances and apparatus are not adapted to the exigencies of the traffic. But when, on the other hand, the accommodation is sufficient to enable the traffic to be worked under safe conditions, when high speed is employed only over a good permanent way in suitable portions of railway, and under proper circumstances, and when good arrangements are made to preserve intervals between the trains, of whatever class, then such extra risk may be in a great measure obviated. Some of the great railway companies have made, and others are making, great progress in providing the necessary remedies. It was stated by Mr. T. B. Farrer, in his evidence before the Select Committee of the House of Lords last year, that the railway companies had then already spent upon the introduction of the block system and the system of interlocking signals, between £700,000 and £800,000, and that they were proposing to spend a great deal more; on a previous occasion, however, it had been stated before the same Committee, by Mr. J. S. Farmer, that, in his opinion, a great deal of expense had been thrown away in tinkering at the signals, in trying to do as little as possible, instead of grasping the thing comprehensively in the first place.

However much has already been accomplished, a good deal yet remains to be done, especially on certain railway systems; and Captain Tyler expresses it as his opinion that it is partly on account of sufficient attention not having been paid in previous years to the various means of safety that some of the great railway companies now appear so unfavorably at the head of the accident list, and partly also because they have found it difficult, with constantly increasing traffic, simultaneously to make

np for past omissions and to keep up with present requirements.

In a circular letter addressed by the President of the Board of Trade to the several railway companies in November, 1873, on the subject of the great increase in the number of railway accidents during 1872, Mr. Chichester Fortescue remarked that a large proportion of these casualties appeared to have been due to causes within the control of the railway companies. "If it may be contended," the circular goes on to state, "that the traffic on many lines has very greatly increased, and with it the risks of railway traveling, it is no less true that it is within the power of the companies to take care that the permanent way, the rolling stock, and the station and siding accommodation, are kept up to the requirements of the traffic; that the officers and servants are sufficient in number and quality for the work to be done, and that proper regulations for their guidance are not only made, but enforced; that pains are taken to test every reasonable invention and expedient devised for the purpose of preventing danger; and that such of those expedients as experience proves to be effective are adopted without undue delay.

"In the face of the facts collected and analyzed by Captain Tyler, and of the numerous accidents of the present year (many of them the subject of Board of Trade inquiries) it is difficult to suppose that such is the case.

"There can indeed be no doubt that methods of working and mechanical contrivances, the value of which has been thoroughly ascertained, have been too slowly introduced, and that there is great reason to believe that sufficient provision has not been made for the safe working of the increased traffic by the enlargement or re-arrangement of stations and sidings, and the laying down of additional lines of rail.

"But whatever may be thought of these and other causes as contributing to the result, the present insecurity of railway traveling imposes upon the railway companies the grave responsibility of finding appropriate remedies for so great an evil."

On the subject of the frequent unpunctuality of trains it was remarked, "The inconvenience, vexation, and loss caused to passengers by this breach of the conditions upon which the companies profess to carry them, constitute in themselves a serious subject of complaint. But the evil arising from unpunctuality does not end here. The surface of the line is disarranged; the chances of accident are multiplied; the trains are forced, in order to make up for lost time, to travel at excessive speed through complicated stations, or under other circumstances where such traveling may be equally dangerous."

It is further remarked that the returns of accidents to railway servants show a lamentable number of casualties, often fatal, in proportion to the numbers employed; and, finally, a hope is expressed that the railway companies themselves "will make every effort to meet the reasonable demands of the public and of Parliament."

The Board of Trade, as the branch of the Government which has to look after the interest of the public in respect to railway traveling, for which purpose it has been invested with special powers, could not with any degree of propriety have passed over, without some special notice, the alarming increase in the number of railway accidents recorded in 1872, which had increased nearly 44 per cent. over 1871, 88 per cent. over 1870, and 196 per cent over 1869. It is not proposed to consider, separately, the replies to this circular which were sent to the Board of Trade, as the remarks which they contained with reference to the principal causes of accident prevailing on railways, will be noticed further on under the different headings to which they respectively belong.

The means of safety which the accidents occurring last year show to be required, are thus given in the last General Report to the Board of Trade:

1. The judicious selection, training, and supervision of officers and servants, and the preservation of good discipline.
2. Maintenance in high condition of the permanent way.
3. Good design, construction, and material of axles.
4. The application of tyre fastenings which will prevent the tyres from flying off the wheels in the event of fracture.

5. Improved coupling of vehicles in trains.

6. Signal and point arrangements with modern improvements, including concentration and interlocking of the signal and point levers, and locking-bolts and locking-bars for facing points.

7. Safety points to goods or siding connections with passenger lines.

8. Increased use of the telegraph, with block-telegraph systems for securing intervals of space instead of illusory intervals of time only between trains.

9. Sufficient siding accommodation for the collection, distribution, and working of goods traffic, so that goods trains may be shunted and marshalled independently, and kept out of the way of passenger trains, and may not encumber and endanger the traffic on the main lines.

10. Continuous breaks, to be worked by the engine-drivers as well as the guards, as occasion may require.

We propose to consider these several means for providing increased security to railway traffic under the following headings, viz.—1. Efficiency of Staff. 2. Maintenance of Permanent Way. 3. Maintenance of Rolling Stock. 4. Signals and Points. 5. Telegraph, and the Block System. 6. Siding Accommodation. 7. Break Power,

1. *Efficiency of Staff.*—It will be readily understood that, all mechanical appliances for ensuring safety being perfect, the efficiency, both as regards strength of establishment and individual intelligence, on the part of the railway staff is yet necessary in order to secure freedom from accident and danger. Even under the most perfect organization, however, the fallibility of human nature must ever be a bar to the attainment of absolute security, but the risk may be lessened to the last practical limit by the maintenance of a fully efficient staff, and the strict enforcement of all regulations laid down for their guidance. In a paper on "Railway Accidents," read before the Institution of Civil Engineers as far back as April, 1862, Mr. James Brunlees, the author, observed that the negligence of servants, their payment, and their hours of working, were matters of the greatest importance, and he remarked that most of the accidents caused by negligence might be traced to ignorance or to inefficiency. The wages usually given by railway companies were too small to command the services of men of intelligence, steadiness, and self-reliance, and, in consequence, inferior men were employed, who were incapable of appreciating the importance and necessity of executing their duty with promptness and exactitude. In the official report to the Board of Trade on railway accidents for the year 1870, Captain Tyler remarked, after enumerating the accidents of the year under their respective headings: "Accidents from all the above causes are more or less preventible, except in so far as it will never be possible, under the best arrangements, altogether to avoid accidents from negligence or mistakes on the part of employees, although it is practicable, under good arrangements and systems, and with good discipline, very much to reduce their number."

In the year 1871, out of 171 investigated accidents, there had been in 121 cases of negligence, want of care, or neglect of servants; in 1872, out of 238 cases, 180 were due to negligence or mistakes of officers or servants; and in 1873, out of 241 accidents, a similar negligence was apparent in 182 cases.

Whatever be the means and appliances provided, or the amount of care taken, the item of human fallibility will always be the cause of a certain number of accidents. But the number of accidents from this cause, as was remarked by Captain Tyler in his report for 1873, may be very much reduced by "improvements in regulations and discipline, by greater care in the selection, training, payment, and employment of competent men in sufficient numbers and for reasonable hours, and by providing them with the requisite siding and other accommodation, with proper signal and point apparatus, with the best means of securing intervals between trains, with sufficient break-power, and with other necessary appliances." It has been argued that railway servants are apt to become more careless in the use of these improvements, in consequence of the extra security which they are believed to afford; but, whilst Captain Tyler remarks that by the results of more ex-

tended experience this argument has received further confutation, Mr. Harrison, the President of the Institution of Civil Engineers, and no mean authority on railway matters, stated, in his inaugural address, that there was an undoubted tendency on the part of engine-men and other railway servants to believe that all these arrangements of the block system and additional signals do, in fact, provide for their safety, and that consequently they do not keep the same look out, or use the same care that they would do on a line apparently less protected, "and that this is the case," he remarked, "observation and inquiry have clearly demonstrated."

Here, then, we find two leading authorities at issue in regard to a statement of fact, and it is, of course, very difficult to draw a fair conclusion between the two. The result of Mr. Harrison's experience seems to prove that, at present, railway servants have not become sufficiently experienced in respect to the true value of signals, and other means of safety on railways, but there is surely reason to hope that, as a body, they possess sufficient intelligence to enable them in time to appreciate more fully the extent to which these safeguards are valuable, and how much also depends upon their individual discretion.

In respect to enforcing discipline, Mr. Harrison observes that the difficulty is becoming constantly greater, as dismissal is no longer a punishment, when employment can at once be had elsewhere; and a reprimand is constantly met with the reply, "Oh! very well, I'll go." This gentleman has found that nothing attaches men more to the service of a railway company than giving them comfortable cottages, with gardens to cultivate.

The efficiency of a staff on a railway depends mainly upon three circumstances: First, the selection of none but respectable and tolerably educated men; secondly, the establishment of a fixed code of rules for their guidance, and seeing that those rules are strictly enforced; and, thirdly, the maintenance of an efficient number of men to do the required work; the payment of liberal wages, so as to keep them in the service; the holding out of prospects of promotion to the most efficient; and the proper treatment of them whilst in the service.

No doubt all modern improvements on railway working tend to increase the expense to the railway companies, but this is a matter for which there is apparently no remedy. "The question of the effect of the labor market on railways, both in their construction and working," says Mr. Harrison, "has come forcibly home to every one connected with them. It is not too much to say that all new works are now costing from 30 to 40 per cent. more than they did a few years ago, and nearly double the time is required to complete them."

As will be shown further on, the adoption of the block system on all lines will necessitate a considerable increase of staff for working it, and with these additional elements of "human frailty" there will evidently exist an increase in the numbers of those to whom the safety of the traveling public will be entrusted, and increased safety can therefore only be expected to result if the rules laid down for the guidance of the companies' servants are, in the first instance, judiciously framed, and afterwards rigidly enforced.

2. *Maintenance of Permanent Way.*—The accidents caused by defects in permanent way are, happily, not nearly so numerous as they were in former years. The art of constructing railways, in the first instance, and of properly maintaining them afterwards, is so much better understood now than formerly, that accidents arising from defects in its observance would be a great slur upon the professional officers of any company. In the year 1854, thirteen accidents occurred from the defective condition or neglect of the permanent way. In the following year thirty-one cases arose from the same causes, but in the year 1856 there were fewer accidents of this description, which fact may be attributed to the greater attention given by engineers to the permanent way, and to the introduction of the fished joint, and of other improved methods of connecting rails. In the year 1857 twenty accidents were caused by the neglect, or imperfect condition, of the permanent way; in four of these the permanent way had been neglected, and in five it had been con-

structed in a defective manner. In 1858, twenty-nine accidents, and in 1859 fourteen accidents, were due to the state of the permanent way.

In commenting on this class of railway accidents, due to permanent way defects, which occurred during 1870, Captain Tyler stated that only nine were attributable to the conditions of the way and works, or to obstructions on the permanent way, etc. "This," he observed, "is a great improvement upon former years, when, say ten years ago, 16 per cent. of railway accidents were caused principally by defects of permanent way; and the improvement is due, partly to the increased strength in some cases of rails and chairs, partly to placing the sleepers in some cases nearer together, and especially to the disuse of wooden trenails for attaching the chairs to the sleepers, and to the now almost universal employment of fish-joints for fastening the ends of the rails together." As to the remedy suggested for this class of accidents, it is remarked that next in importance to proper maintenance, and even as part of it, is the question of discipline amongst those employed in repairs, with a view to ensure, as far as possible, that due warning shall be given to engine-drivers when a rail has to be taken out, while the road is being lifted, or whenever the line is not in a fit condition to be run over at speed.

Twenty-six accidents occurred in 1871 owing to defects of construction. These defects, it was then pointed out, were not as promptly corrected as they ought to have been, as new materials were supplied, on many lines of railway; each company, or each individual officer, waiting too often to buy his own experience, and profiting too little by the experience of other companies. Defects of maintenance, which appeared in nineteen cases, occurred partly from the over-work of materials, and partly from the want of more careful supervision, and of more careful record and comparison, from which much valuable information might be obtained. The number of accidents due to defective construction of road or works was four in 1872, and six in 1873, and to defective maintenance of the same, sixteen in 1872, and twenty-four in 1873.

It may perhaps be considered that forty accidents in one year, upon all the railways in the United Kingdom, due to defective construction or maintenance, is hardly above the number that might be expected to occur from such causes, considering the vast amount of traffic which now takes place in the neighborhood, more particularly, of large towns and cities, but it must be remembered that these constitute a class of accident which is preventible by the exercise of due care on the part of the permanent way staff, and proper supervision during construction. It is, therefore, one which should not be seen in the official returns, unless accompanied by some such causes as exceptional floods, or other reasons to show that they were not occasioned by any laxity of duty or neglect of ordinary precautions on the part of the railway company or their officials.

Maintenance of Rolling Stock.—With regard to locomotives, instances do rarely occur—and they were more common in former than in recent years—of boiler explosions, due in some instances to want of proper care in the selection of water for their use, and in others, to a faulty mode of staying the boiler. These causes of accident are to be avoided by frequent inspection, by which the earliest intimation of any deterioration may be obtained, and the employment of weakened or worn-out boilers be discontinued. During the seven years from 1854 to 1860 twenty-one locomotives exploded, but in the annual returns to the Board of Trade only two accidents from this cause are stated to have taken place in 1870, and two in 1873; no record of a similar accident appearing in the two intervening years.

The most common accidents to rolling stock are the breaking of the axles and wheel tyres. These cases may be traced generally to one or other of the following causes: sometimes they occur in the winter months, owing possibly, in some degree, to the rigid state of the permanent way in frosty weather; some are due to the use of bad iron or steel, and others to defects either in the welding of, or in the mode of attaching, the tyres of wheels. The existence of flaws in either axles or tyres may completely escape detection until they are discovered upon the occurrence of an accident, and such

cases must be included amongst the risks which cannot be foreseen or avoided. The high speed at which trains travel as a general rule must subject both tyres and axles to very severe blows and jerks, especially when passing over points, or portions of line that are out of repair, and uneven, and it is in such cases that flaws or cracks are most likely to result in a complete fracture. "There is no satisfactory test," said Captain Tyler, in his report for 1870, "to which axles can be subjected from time to time in the course of running, as far as is known, by which flaws can be detected." With regard to fracture of tyres, it was stated in the same report that in two cases the tyre was attached to the wheel by means of rivets through holes bored in the tyre, and it was remarked that the "old system of boring holes through the tyres is essentially a vicious one, and is particularly undesirable in the case of steel tyres. It affords no security in the event of fracture, and even leads to increased risk of fracture, in consequence of the weakening of the tyre at the sides of the rivet holes.

In 1871 there were twenty-two accidents of this class, in which three persons were killed and thirty-four were injured; in 1872 there were seventeen accidents, occasioning the death of two passengers and five servants of companies, and injury to forty passengers and eight servants of companies, whilst in 1873 there were twenty-three accidents owing to the same causes, killing ten passengers and two servants of companies, and injuring fifty-four passengers and seventeen servants of companies. The chief methods recommended for adoption with a view to avoiding accidents from the breaking of tyres, consist in the use of improved modes of fastening them to the rims, so as to prevent them from flying off the wheel. They may fail from the brittle nature of the material, or from defects of manufacture, or from being too tightly shrunk on the wheel, and they have frequently failed from one of these causes, or from a combination of them. The danger consists, not in the fracture, or in the tyre becoming divided, whilst running, into two or more parts, but in the probability of the tyre, which is, or ought to be, in a state of tension on the wheel, flying suddenly and violently from it when fracture occurs, and this danger is greater with steel than with iron tyres.

3. *Signals and Points.*—During the seven years from 1854 to 1860 inclusive, as many as eighty-eight accidents happened from the use of improper or inefficient signals. Accidents have been caused by the total want of signals, especially at sidings, others have arisen from their defective form, or from their bad position. Many accidents have occurred in connection with distance signals; in some cases they have been placed so near to the station that the engine-driver has been unable to stop within the space allowed. It was observed by Captain Tyler in 1870, that out of sixty-one collisions, independent of the collisions at junctions or level crossings, thirty-one, or more than half of them, were due to defective arrangements with regard to signals or points, but that in twenty-eight cases out of these negligence was combined with the defects, and that the latter contributed more or less to the negligence; and out of eighteen collisions at junctions there were ten cases in which defective signal and point arrangements were the cause. In 1871 there were fifty-three accidents caused by defective signal and point arrangements, or want of locking apparatus; in 1872 the number of accidents due to similar causes was seventy-one, and last year it was seventy-eight, so that this cause of accident would appear to be growing rapidly in importance.

When trains were few, and the speed at which they traveled was moderate, a comparatively crude method of signaling sufficiently answered every purpose; with the increase of trains, the complications of junctions, and the greater difficulty that consequently existed in controlling a number of signals at any one point, it became necessary to place all the signals and point levers in or around the signal cabins; and, in order to afford a better view to the signal man, the cabins were raised to a greater or less height above the ground, and placed in convenient situations, according to local circumstances. But even then, when the control was more conveniently placed in the hands of one man, there was still, as the levers in or near a cabin became

more numerous, a liability to mistake, from the signalman pulling over a wrong lever; or the levers were fastened over by blocks of wood, which the signalman forgot to remove; and to prevent such mistakes, and serious accidents resulting from them, it became further necessary to interlock the levers with one another. By 1860 many improvements had been introduced upon the interlocking system, and the inspecting officers of the Board of Trade began to insist on the use of locking apparatus at the junctions of new branches with existing lines.

By the application of locking and other apparatus it is possible to prevent nearly all accidents from collision occurring, in the ordinary way of working, in consequence of any mistake of the signalman. Conflicts between signals, and conflicts between points and signals, may alike be avoided; and a good combination of locking-bar and bolt may be made to insure that the facing points are completely over before the proper signal is lowered, and may also prevent them from being moved during the passage of a train. It is, of course, impossible to provide against all the contingencies which may arise—such as, in certain cases, against the absolute neglect of drivers to pay attention to the signals made to them; or such as a signalman, when two trains are running towards a junction at one time, setting his points and lowering his signals first for one of them, and then altering them and preparing for the second train, without allowing time for the first train to stop short of the junction. But provision may be made, and is made to some extent, even for the contingency of an engine-driver neglecting to obey signals.

In a paper recently read before the Institution of Civil Engineers, by Mr. R. C. Rapier, a detailed description of signals and points was given, besides an account of different methods of interlocking the two, so as to avoid accidents which might occur in the event of wrong signaling. It would be impossible to follow out that paper in detail here, but we may briefly state that it was there shown that the mere connection of switches and signals was not sufficient, but that effective interlocking required the movement of the switches to be completed before the alteration of the signals could be made, and *vice versa;* whilst, as regards facing-points, it was stated that, although it was desirable to avoid them as much as possible on a line of light traffic, the use of facing-points, properly controlled, might be made one of the greatest safeguards where trains were frequent, and traveled at different rates of speed.

5. *Telegraph and the Block System.*—In two papers on "Railway Accidents," by Mr. Brunlees and by Captain Galton, read at the Institution of Civil Engineers in 1862, it was deduced from statistical tables that the great majority of accidents were attributable to preventible causes, and that, of these, 27 per cent. were due to the absence of the electric telegraph. The advantages of the telegraph in connection with the working of railways were dealt with in an able paper by Mr. W. H. Preece, which was read at the Institution of Civil Engineers as far back as January, 1863, and although all the views expressed by him on the subject at that time have not met everywhere with approval or adoption, the system generally has come to be recognized as absolutely necessary for the safe working of any line of railway, and it forms a most important element in the now universally adopted block system.

The first attempt of a block system introduced on railways was by maintaining a presumed time interval between trains; this plan, however, failed, because those intervals could not in practice be observed; and the permissive system for reducing the time intervals by the aid of the telegraph, and sending trains timed to travel, and capable of traveling, at various speeds, one after another, into the sections, with a caution to each, may also be considered to have failed, because it does not afford sufficient protection to the traffic. Under these time systems collisions have occurred from engine-drivers slackening their speed to avoid collision with trains in front of them, and being run into by trains behind them. The greater the variety of speed between the trains, the more does the weakness of such systems become apparent.

The proposal to divide the line of railway into telegraphic sections, and thus

to preserve space intervals between trains, was made by Mr. (now Sir William) Cooke, as far back as 1842, and was first practised, it is believed, on a portion of what is now the Great Eastern Railway, in 1844; and, subsequently, a train telegraph system was established on portions of the London and North-Western Railway. This latter, however, was not a block system, or a space system, but a time system worked with the aid of telegraph instruments, and it is now known as the permissive system. As regards the block system, there are many descriptions of instruments for working it, and various rules and regulations applicable to it on different lines of railway. The main principle involved is simply by the division of a line into block sections, and allowing no engine or train to enter a block section until the previous engine has quitted it, to preserve an absolute interval of space between engines and trains. This may be done mechanically or electrically. Any means of communication with which the signalmen may be provided will enable them to inform one another of the approach of a train, of its entrance into a block section at one end, and of its exit from that block section at the other end.

Mr. Harrison, the President of the Institution of Civil Engineers, has stated that the block system will, as soon as it is possible to complete the necessary works, be introduced throughout the whole of the railways in England. It was stated by Mr. Farrar, before the Select Committee of the House of Lords last year, that the railway companies had already spent upon introducing the block system, and the system of interlocking signals, between £700,000 and £800,000, and they were proposing to spend a great deal more. Besides this expense there is a considerable annual cost to be incurred in working those systems; the increased cost of the staff alone is estimated for the Great Eastern Railway at £13,860, and on the Midland at £130,000 per annum. In the case of the North Eastern Railway it is calculated that on the completion of the block system, the number of signalmen will be increased from 500 to 2,000. Mr. Rapier, in his paper to which we have already referred, shows that the probable cost of the interlocking and block system on fourteen of the principal railways would be about ½ per cent. on the whole cost of the lines, and that then their carrying power might be so increased that three times as many trains could be run on the block system as without it, and with greater safety. The probable cost of maintaining the block system was stated to be about 2½ per cent. on the traffic receipts, and this comparative percentage was less on the lines which had a great number of points to protect than on some of the light traffic railways.

6. *Siding Accommodation.*—It was pointed out in the Report to the Board of Trade on Accidents that occurred during 1871, that collisions at stations often occurred from the want of accommodation at the stations or sidings, passenger lines being unduly obstructed from the want of sidings in which to place slow or stopping trains, or in which shunting may be performed. The same deficiency of accommodation may also be the indirect cause of collisions on the line between stations, when, for instance, from the want of siding accommodation, a slower train is despatched in advance of a faster one, without a sufficient interval between them to allow of its proceeding forward to the next place of refuge before it is overtaken, and it is stated that the want of improvement in, and addition to, the siding accommodation, combined with the want of modern appliances for working the points and signals from suitable cabins, and interlocking the levers with one another, and of telegraph-working, for assisting in protecting an obstructed station, have principally to answer not only for the accidents themselves, but also for the negligence of the servants by which those accidents were more or less directly occasioned.

7. *Brake Power.*—The subject of brake power is one of especial importance, many lives and much property being hourly dependent, in a greater or less degree, on the power and efficient state of the brakes. It has been found that most of the collisions which have occurred might have been prevented had those in charge of the trains possessed the power of stopping within a few hundred yards. This is more par-

ticularly necessary on account of the high speeds and heavy trains now adopted on all lines. It is therefore essential that there should be ample brake power to each train, and, whatever system may be adopted, it should be powerful, simple, and capable of being applied in the shortest possible time. On certain railways, where the necessities or convenience of the companies have been the means of inducing more rapid improvements in this respect, systems of continuous brakes have for many years been in successful operation; and the experience of these lines has left no doubt of the value of such systems of brakes. Amongst the simpler means of providing extra brake power are: increasing the numbers of guards and of brake vehicles; enabling a guard or brakesman to apply the brakes of two adjacent vehicles; allowing the guards and brakesmen to walk through the trains, and to apply the brakes of the various vehicles provided with them; or by such a system as may enable a guard from his own van to apply the brakes of several vehicles, in which may be combined an economy in guards with efficiency in brake power. In the use of any good system of this description, it becomes unnecessary to skid the wheels of brake-vehicles, and flat places in the wheel tyers are thus avoided. Perhaps the most perfect system of continuous brakes yet introduced is that which enables the engine driver to control the train, and by means of compressed air to apply all the brakes at once without the development of any manual exertion.

The limit of space to which we are necessarily confined for a single article has prevented any detailed account of the various methods of intercommunication in trains, which, by the Regulation of Railways Act of 1868, is directed to be provided in every train carrying passengers and traveling more than twenty miles without stopping, or of the several other minor arrangements suggested or introduced, with the view of more effectually securing the safety of passengers.

With the adoption of the improved methods of interlocking signals and points, and of the block system, no doubt very considerable addition is made to the safety of travelers, but the companies are thereby put to great additional expense, both in first cost and for subsequent maintenance, for which the only return they can look to is an increased immunity from accidents. To insure absolute security is not, however, possible, by the adoption of any means hitherto suggested. The introduction of the block system necessitates the maintenance of a considerably increased staff of signalers, and at the same time it introduces so many additional elements of human fallibility, whose liability to err can only to a limited extent be guarded against by the employment only of competent men, and the strict enforcement of such rules and regulations as it may, in each case, be considered advisable to frame for their guidance.

THE FUTURE OF ARCHITECTURE.

From "The Builder."

Recent discussions have shown that there is no desire on the part of the profession to disguise the defects, the demerits and the failures, which have in so large a measure exhibited themselves in connection with our modern architecture, and the system to which we are indebted for our architects. The main practical conclusion we have now to face is that the production of our architecture has passed into the hands of an immense multitude throughout the country, of whom it is impossible to say that they are the fittest minds for the task they have undertaken, or, that if so, there is any guarantee of their qualifications. This is a condition of things with which it is impossible immediately to deal; any amelioration must be gradual, progressive and prospective. No system of compulsory examinations could be set up, or the absolute necessity of a diploma before practice enforced, as things now are; and we fear that the offer of voluntary examination, and the advantages which might accrue in professional

status by being fortified by such a guarantee would be responded to a very slight extent. Hence, as we have said, any remedial measures must be regarded chiefly in their prospective aspect. What we have now to determine is, whether we can fairly and safely hope that there are elements in the present condition of things, which will, if slowly, yet surely, work their own cure. In the present intermingling and jostling, as it were, of engineer, builder, and architect on the same field, may it be hoped that the gradual improvement of public taste, and a higher tone in the patronage upon which architecture depends, will eventuate in a demand which will be unable to tolerate that which now passes for sufficiently good architecture, and in the end so far eliminate the bad, that false, mediocre, and pretentious work will sink to its level, and that which the true architect can alone supply meet with its fitting place? We are very distinctly of opinion that it is fallacious to indulge such a hope. It must be a fact within the knowledge of all who have thought upon fine art in any of its branches, be it architecture, painting, sculpture, music, or poetry, that "taste" is a most variable quality, and grows by that which it feeds upon. Illustrations innumerable might be given as to this, but we will confine ourselves to a single cognate instance. Can there be a question that, even among minds of an average range of culture and susceptibility to æsthetic influence, that after being accustomed to a low type of art, say in architecture, and perfectly satisfied with this, because knowing no higher or better, the sight of indubitably finer buildings would at once raise the taste, and render that before tolerated with complaisance almost insufferable. Now, this we take to be the key of the whole question of an advance in the public taste as to art, and it decides at once what we believe must be found to be the truest ground upon which any hope can be built, that the "architecture of the future" will prove any positive advance upon what is now in its main extent a somewhat mongrel and unsatisfying state of things. The public taste can become debauched or perverted by showy, pretentious work, which will not bear investigation upon any principles of true architecture; and which, if capable of startling and creating a "sensation," will not answer to that one criterion of true art, it sufficing to afford an abiding source of pleasure. All this character of art is increasingly abundant around us, for evidence of which we have only to point to the majority of new edifices which arise in the process of rebuilding now so rapidly going on. The issue of all this cannot be such a purifying and ennobling of public taste and art-patronage as will lead to the production of works which will stand the test of lasting admiration, but rather their degradation, and will leave few precedents to posterity such as the thoughtful, noble works of Greek and Mediæval times have been to subsequent ages. How, then, are these tendencies to be corrected and the foundation laid for a pure and noble system of art-culture and development? While our architects, or the large body who undertake our architectural works, are either incapable of anything better, or persist in pandering to a false taste, there *can* be no improvement, and the present conditions of patronage are such that the chances are that the meretricious will outbid a higher and truer class of art. Nor will improvement come, as some fondly imagine, by a dissemination among all classes of some knowledge of the principles and practice of art. The *utmost* that can be done in this way will go so little towards forming a correct taste that it cannot be taken into reckoning with what we have stated to be the practical means which creates, fosters and maintains true taste in art, viz., the exhibition of instances of such noble works as gradually, if not at once, make themselves felt, and adjust the standard of what is satisfying against inferior and ignoble work. The consideration of this question has often been before us, and we can only resort to what we have already stated, that, in the present condition of English architecture, the admitted failure of the pupil-system, the impossibility of enforcing a system of examinations and degrees, and the fact that our present architecture is in the hands of such a numerous band of practitioners and aspirants, there is no *immediate* prospect of the application of any means which can act as a direct remedy. But there is a *prospective* one,

and this we think, to all who give the subject a candid and thoughtful attention in its present aspects and bearings, will be found to consist in the establishment of architectural colleges. These would provide an arena for the combined and sustained study of architecture in all its fulness as a fine art unaffected by the chance influences of misapplied patronage and misinformed public taste to which our architects are now necessarily subject, and, if rightly organized, would attract only that class of minds which find in architecture an expression of the art-faculty with which they are endowed. The cultivation of any art beyond the limits of those who can enter upon it with some sort of original creative faculty is a mistake and waste of effort, and in modern times has given us that plethora of mediocrity in nearly all the fine arts which has been their bane and misfortune. But architectural colleges of the nature we have in view, would send forth trained bands of men agreed upon the common principles at the base of all architectural practice in varying constructive modes and the unity of decorative effects; which, as matters of ascertained truth could not be diverged from, as now, at the dictate of any caprice; while leaving a full field for the exercise of that individuality and originality which must ever form a considerable factor in all true art.

It is comparatively easy to point out the defects of our present architecture and the system which promotes them, and, by a converse process, to arrive at what might be regarded as an ideal condition of things, which might well be taken to be such a state of the public taste as could not tolerate the exhibition of bad architecture; and hence the necessity that our architects should be only those who could satisfy such a high demand. But, as we have seen, the cultivation of the public taste is the direct product of that which is placed before it, and higher results can only be attained by beginning with those in any age and nation best calculated to be the purveyors of art to those who have it not. There is one all-important point in regard to architecture which applies with less force to the other fine arts. An architectural work, whether we will or not, *must* come under our notice, and must exercise an influence from which we cannot escape, either for good or evil, in the elevation or lowering of our taste. Herein lies the *raison d'etre* for seeking to confine the production of our architecture to the best minds and hands; and, after the fullest consideration of the whole subject, in view of the actual condition of things amongst us, there seems nothing which offers any prospect of a remedy other than the combining of the best contemporary genius and talent in the study of architecture in such a form as shall be able so to take the lead that the public will not be long in judging what are the true art-products and what are not, and in rendering honor and aid to those alone entitled to deserve them. A system of architectural colleges effecting this result would soon winnow the chaff from the wheat, and be able to dispense all those distinctions that are now wanting in the architectural profession.

We cannot but regard the present as a time of crisis in the history of architecture in this country, and though we have before in a detailed manner pointed out the place and special value of something of an architectural collegiate system for the satisfactory cultivation of the art, and the formation of a genuine architectural profession in the midst of the divided heterogeneous influences of the present time, we would again commend this aspect of the subject to the earnest attention of our thoughtful professional readers. Art now stands in a different relation to society to what it did in any former time; we cannot restore old conditions, but must meet the new ones as best we may, and the two points which have now to be conciliated, are the providing scope for the best art-faculty amongst us, and such a cultivation of the public taste as shall reduce patronage of the inferior and mediocre to a minimum. A well-organized system of colleges, whether affiliated to the universities or not, would effect the one, and general art-congresses in their public and popular aspects would do not a little in effecting the other. It is to be hoped that the admirable bequest of Chantrey for the encouragement of the highest art in painting and sculpture may meet with some imitator in the interests of

architecture; a similar sum in trust in the hands of a few of our most devoted and distinguished architects and connoisseurs would go a long way towards setting on foot an influence upon our architecture such as the present mercantile and fictitious repute notions which govern its patronage can never afford.

BREECHLOADING ORDNANCE.

From "Engineering."

In a recent communication to the *Times*, through Mr. Alfred Longsdon, Herr Friedrich Krupp, of Essen, has contributed some valuable information upon the subject of cast steel breechloading guns, information which no one was in a position to supply but himself, the largest private maker of ordnance in the world. The main object of this letter was to throw some light on the confused notions existing as to the powers of resistance of cast steel guns, and the reliability of the breech mechanism employed. With respect to the rumors that in the course of the Franco-German war 200 field pieces failed, we are assured that not one gun burst during the whole of the campaign on the German side, which was supplied wholly from the works at Essen, while the breech mechanism in all cases showed its complete efficiency, and not a single failure of it is recorded.

Mr. Longsdon next, taking wider ground, gives us statistics as to the failures which have taken place among the 13,000 steel guns manufactured by the magnificent establishment he represents. These failures, he assures us, are limited to seventeen. Out of this extremely small number eleven may be fairly thrown out of consideration; they were imperfect guns as far as the breechloading mechanism was concerned, having been made, tested, and destroyed before the present highly efficient system of breechloading had been adopted. Of the remaining six guns Mr. Longsdon gives us a record as follows:

In 1865 a 9-in. gun burst explosively in Russia after the 410th round. This gun was a converted muzzleloader, and failed under excessive charges.

In 1866 a second 9-in. gun burst explosively in Russia after the 56th round.

In 1869 an 8-in. gun burst explosively in Berlin after the 650th round.

In 1871 an 11-in. gun burst at Fort Constantine.

In 1872 a 15-pounder burst in Berlin after 557 rounds.

Mr. Longsdon has, however, omitted to mention several other failures of his guns, which we may add to the above list. We take them from a paper read by Major Haig before the Royal Artillery Institution.

In 1865 a Krupp 9¾-inch steel gun burst with a moderate charge of powder, a Prussian committee attributing the failure to inferiority of the metal.

In the same year a 9½-in. gun of Krupp's steel burst in Russia at the 66th round.

In the same year an 8½-in. similar gun burst at the 96th round.

In 1866 a Krupp field gun burst explosively at Berlin, killing three cadets.

In 1866, during the Austro-Prussian war, six Prussian steel field guns burst.

In January, 1867, a 7-in. Krupp gun burst at the second round of proof at Woolwich.

In the same year a 4-pounder burst at Tegal, near Berlin.

In 1868 an 8-in. Krupp gun burst on board a Russian frigate very destructively, killing and wounding in all 12 men.

In 1872 an 11-in. Krupp gun burst at the chase, and blew about 3 ft. off the muzzle.

The correctness of the above list is easy of verification, and it is somewhat to be regretted that Mr. Longsdon should have overlooked these important instances of dangerous failures, as they modify considerably the inferences to be drawn from his letter. In statistics of this kind nothing is so necessary as unassailable accuracy; and we should be

glad to learn that Major Haig's statements are incorrect, although we have not the slightest doubt that the failures enumerated by him did take place, and the value of Mr. Longsdon's communication to the *Times* will lose all its value if we find that the assurances it contains are unreliable. And before accepting the assurance that no Krupp field guns failed during the Franco-German war, we are obliged to hesitate, because since the publication of Mr. Longsdon's letter, the public is assurred that in numerous instances the Krupp field guns have burst during that period.

One correspondent, replying to Mr. Longsdon's letter, states that in 1871 he was assurred by an officer on the Headquarters staff of the German army, that out of 70 long breechloading 24-pounders, 36 became unserviceable during 15 days' firing, and that had the bombardment been continued for another week, the German batteries would have been silenced owing to failure at the breech. Again on the Loire and in Brittany 24 field guns became unserviceable, chiefly through their own fire. A second writer goes further and maintains that about 200 field guns were wholly or partially disabled, two or three through the enemy's fire, and the rest through defects in the breech mechanism and bursting of shells in the bore. It is only fair to state, however, that these damaging allegations are advanced anonymously, and require corroboration.

We have to assume, therefore, despite Mr. Longsdon's assurances to the contrary, that a considerable number of explosive failures of Krupp guns have taken place; but we would call attention to the fact already recorded by us, that none of them are proved to have failed by reason of the breech mechanism (after it had attained its present form), but through the unreliability of the metal itself.

From the experience thus gained it may be fairly assumed that the steel employed in the heavy ordnance on the Continent is not so reliable as the steel and iron used in combination in our Woolwich guns. A steel gun may show very high powers of endurance, as evidenced by many admirable examples of Krupp's work, but it is impossible to be absolutely sure of the absence of any flaw or other unseen element of weakness, and when it does yield, it almost certainly yields with violence. Sir Joseph Whitworth claims, and indeed has shown by numerous experiments, that the homogeneous metal he manufactures is entirely reliable, that it exhibits very high powers of resistance, and when forced to yield by the overwhelming nature of the powder charge it does not break with violence. But for all practical use to this country the employment of this metal has not gone beyond the stage of experiment, and we fail to understand why it has not been tested in the A tube of one of our large Woolwich guns. The Woolwich authorities are, we feel sure, anxious to adopt superior materials whenever possible, and, therefore, they can scarcely be responsible for not having tried a metal, which is, according to the high authority of Sir Joseph Whitworth, far superior to any that has ever before been employed.

But even with the materials at their disposal the guns made at Woolwich show no such annals of explosive failure as do those of Essen manufacture. Indeed, the great merit of our heavy ordnance is its almost perfect non-liability to burst explosively, but that it yields gradually, giving timely warning of approaching failure. The admirable combination and arrangement of material used in the Woolwich guns is equalled nowhere, and in our present state of knowledge cannot be surpassed, and the reasoning in the Text-Book of the Construction aud Manufacture of Rifled Ordnance, published in 1872, holds equally good to-day. "Steel from its hardness, high tensile strength, and freedom from flaws and defects, is better suited than wrought iron for the inner barrel of a gun, while its brittleness and uncertainty render it unsuitable for the exterior portions. The construction adopted in the service is, therefore, founded on correct principles, as far as the materials and their arrangements are concerned, and the correctness of the principles has been proved by twelve years' experience, during which period thousands of guns have been manufactured and issued, and in no one instance has a gun burst explosively on service, nor has a single life been sacrificed." Of the ordnance of no other great power in

the world can this be said, and whether we compare our guns with the composite cast iron and steel structures of France, the steel guns of Germany and Russia, or the obsolete cast iron pieces of the United States, our superiority of design, of materials, and of workmanship, is as marked as it is reassuring. That reforms may have to be made in our mode of rifling, and that possibly, nay probably, we shall follow the practice of Continental nations, and abandon muzzle in favor of breechloading for large calibres, does not alter the main fact of the superiority of our heavy guns.

The durability of the breechloading system, which we have described and illustrated on previous occasions, has, as we have stated, been called into question by the correspondents to the *Times*, whose letters was called forth in reply to Mr. Longsdon's communication. The evidence on this point, however, is very vague, and on the other hand there is very powerful testimony in favor of the system. To apply it to one of our heavy guns will be (if such a decision be arrived at) but a small matter, and we shall then have ample opportunity of judging for ourselves of the actual merits of the mechanism as carried out at Woolwich.

At the close of his letter to the *Times* Mr. Longsdon refers to the claims of Mr. L. W. Broadwell, of Carlsruhe, to the invention of the breechloading mechanism associated with Mr. Krupp's name, and as we have on previous occasions referred to the same subject, his remarks have a special interest for us. But as Mr. Longsdon has favored us with a communicttion touching the same question, and dealing with it in much detail, we propose only to make a passing reference to the matter now, and to defer our criticism of the letter addressed to ourselves until Mr. Broadwell himself has been allowed time to reply.

Mr. Krupp, writing by Mr. Longsdon, accedes to Mr. Broadwell the invention of a detail originally connected with the system, a detail obsolete indeed, but which at the time was of considerable importance. "To Mr. Broadwell belongs the merit of *inserting the ring in the face of the breech block*, a very useful invention." The italics are our own. This detail was patented by Mr. Broadwell in 1861, yet in 1862 we find precisely similar rings inserted in the breech blocks shown in Mr. Krupp's specification. Thus while a clear acknowledgment is made of the fact that Mr. Broadwell was the originator of the idea for placing the ring in the face of the breech block, endorsing our own statement, we have no explanation why the same detail was patented by Mr. Krupp more than a year after.

But we are assured that the "Broadwell ring" is a misnomer, it "wrongly goes by his name," and should, by inference, be called the Krupp ring. Reference must be made here, we presume, to the perfected form of ring, patented by Mr. Broadwell in 1865, and improved subsequently. Yet in Mr. Krupp's specification dated February, 1865, two months before that of Mr. Broadwell's just referred to, we only find drawings of the ring inserted in the face of the breech block, the "very useful modification," the merit of which belongs to Mr. Broadwell. In the latter gentleman's specification dated April, 1865, the first arrangement of a specially formed ring fitting in a suitable channel in the bore of the gun, and bearing at the back upon a circular plate in a recess in the breech block, is shown. For many months before this patent was applied for, Mr. Broadwell had been in St. Petersburg, discussing his plans for breechloading ordnance with the Minister of War, and it was while there that he introduced this improvement on his original idea. In July, 1865, about three months after his application for a patent, the Russian Government had accepted his system, with a formal declaration of which the following is a translation. "After numerous experiments made by the Imperial Russian Government in the gas check ring, the invention of Mr. L. W. Broadwell, citizen of the United States, this ring has been recognized as perfectly attaining its object of preventing the gases from the burning powder to escape through the transverse opening in the breech, through which the closing mechanism is introduced, and it is in consequence of these highly satisfactory results that the said Broadwell ring has been introduced in the Imperial Artillery, for use in cast-steel breechloading guns. (Signed) Barantzoff, Aide-de-Camp Gen-

eral." Thus, while Mr. Krupp freely acknowledges the originality of Mr. Broadwell's insertion of the ring in the face of the breech block, dates and unquestionable authority award him the undoubted merit of the improved ring, universally known by his name.

We have dwelt at some length upon this point, having been led to do so by the remark we have quoted from Mr. Longsdon's letter to the *Times*, and here we leave the subject for the present.

We would, however, take this opportunity of assuring Herr Krupp and Mr. Longsdon that the only object we have in view, is to arrive at, and place on record the exact truth connected with this interesting question.

ENGLISH LIGHT-HOUSES.

From "Illustrated Washington Chronicle."

WITHOUT question the noblest monuments of civilization are those created to promote the happiness and protect the lives of people. It has been justly observed that a government, which guarantees unto its citizens unrestrained freedom, and neglects to provide the safeguards that insure the enjoyment of life, is far inferior to that which, though exercising a proper and even severe firmness in the administration of its laws, uses the means at its command to increase the safety and consequently the prosperity of those it governs.

For proof of this we need but glance at the respective conditions of two different classes of nations. Those which have acknowledged the importance of securing the welfare of their inhabitants by a wise system of public benefits, and the governments which have practically allowed the affairs of the people to take care of themselves.

Of the public benefits referred to there is none greater than that which insures the safety of the mariner—the light-house. Without it commerce would ever remain dwarfed in its proportions; for the perils of the deep, unless lessened by these humane contrivances, would prove too appalling for those hardy enough to brave its mitigated dangers. The countries which have paid the most attention to this important matter are those that have attained the highest position in the commercial scale. It may be asserted that light-houses were constructed by these nations because the safety of their vessels depended upon their existence. But it may be assumed with equal certainty on the other hand that a nation with harbors difficult of access, and unprovided with the warnings necessary for the security of ships in approaching or departing, can never become a great maritime power, for the reason that circumstances combine to prevent its growth in that direction.

This fact has been recognized since the birth of enterprise, although it was reserved for the moderns to bring the light-house system to its present complete and efficient condition. Foremost among the nations that have distinguished themselves in the erection of these valuable assistants to navigation are France, England, Scotland, and the United States. The peculiar conformation of the English coast rendered the construction of many of her light-houses an imperative necessity; without them it would have been impossible to create or preserve after having created, the vast navy of vessels bearing her flag that find their way to and from her ports every day in the year.

The growth of the light-house system of the countries mentioned to its present effectiveness has not been precipitate. It is the result of centuries of patient work, fortified by a continued determination to achieve excellence in this direction.

In this number of the *Chronicle* we give illustrations of a few of the most prominent light-houses of England. We are mainly indebted for the accompanying descriptions to an interesting public document embodying the results of Maj. Elliot's corps of engineers, United States army, tour through Europe, made for the purpose of examining and reporting

upon the light-house systems of foreign nations. At the time of the first appearance of the report we took occasion to refer to it as a document worthy the most careful study on account of the quantity and value of the carefully-prepared information it contained, but as the work is inaccessible to the general public we reproduce such illustrations and extracts as may prove most entertaining. We regret that limited space precludes our copying more extensively, for we seldom come across a public document from which so many and valuable extracts can be made.

The Roman Pharos, now one of the most precious relics of ancient England, is situated within the walls of the Castle of Dover. The antiquity of this monument no doubt exceeds that of any light-house in Great Britain. It has not been used since the Conquest as a warning tower to mariners. From the time of its erection, which was supposed to have been during the reign of the Emperor Claudius, about A. D. 44, up to the period of the invasion by the Conquerors, large fires of wood and coal were maintained upon it. This method was the earliest adopted to guide sailors, and it finally gave way to the reflector, which was in turn supplanted by that triumph of skill, the Fresnel lens. The Pharos is built of brick, of a light red color, about fourteen inches in length and not more than one and a half inches thick, but little more than the thickness of the joints, which are filled with a mortar composed of lime and finely-powdered brick. Its preservation is doubtless owing to the circumstance that the tower was converted into a belfry for the church of St. Mary, and was surrounded by walls of stone, which have nearly succumbed to the action of the elements, and have exposed the old Roman work.

The great electric light at Souter Point, three miles below the mouth of the River Tyne, is a modern scientific triumph. Its location is such as to present serious obstacles to the effective construction of a proper guide to mariners owing to the smoke from the cities and towns on the river, including Newcastle, combining with the frequent fogs, but these have been overcome in a great measure by the introduction of a light which sends over the North Sea its flashes, each of which is equal in intensity to the combined light of *eight hundred thousand candles.* The lenticular apparatus is of the finest possible workmanship, and utilizes every ray of light generated by the electrical machines in the tower.

The Outer Farne or Longstone Light-house, better known to the public as the home of Grace Darling, is situated at the mouth of the Tweed. It is the most northerly of the sea lights of England, on the shore of the North Sea, and is in plain view from the light at St. Alb's Head, the first of the Scottish lights. It is a rock light-house, and its peculiar construction is well illustrated in our engraving. The sea rolls with great violence in the vicinity, and for this reason it was found necessary to surround the tower with high walls to protect it from the encroachments of the waves in time of storm. The daring act of Grace Darling in rescuing nine men from the wrecked vessel Forfarshire, when she struck Hawkin's Reef, must ever throw around this spot a poetic glamor. The house that sheltered heroism of this kind must always be interesting to those who have a sympathetic heart in their bosoms.

The Eddystone Light-house, off the coast of Devonshire, is famous for its great strength. The first light-house on the Eddystone was completed in 1698. Its existence was brief, however, as it was destroyed in a violent storm in 1703. The keepers and the builder lost their lives by the catastrophe. A second light-house was constructed here in 1709, which was destroyed by fire in 1755. The present Eddystone was commenced by John Smeaton in 1756, and completed in 1759. It is a marvel of solidity and strength. The material employed in its construction is stone. The joints are dovetailed, rendering it simply impossible to move one stone without displacing the rest. This has proved the model for all light-houses subsequently erected, except in immaterial details. The science of illumination as applied to the Eddystone was far behind the science of construction, and while Smeaton sprang at once from the prejudice of his time to a full conception of the true principles which should govern the construction of

a work of this character, it remained lighted for many years as at first, by "*twenty-four candles burning at once, five whereof weighed two pounds.*" The quaint expression in italics are extracted from Smeaton's narrative of the building of the Eddystone Light-house. Reflectors were not introduced until early in the present century, and in 1845 these in turn gave way to a second order Fresnellens, the beam from which, with its Douglass burner, is equal to 4,650 candles.

This was the first catadioptric apparatus ever constructed.

The Wolf Rock Light, ten miles from Land's End, was commenced in 1862, and its construction finished in 1869. It is built on a rock two feet below high water. This rock for centuries was the dread of mariners, as in violent weather the sea sweeps completely over it. But since the erection of the staunch house it has been shorn of all its terrors, and that which was once a serious evil is now converted into a positive good, the location and its distance from the land rendering it a most valuable guide for entrance into the English Channel. There is no light-house in existence, however, that has cost more labor than this. The fury of the elements in the neighborhood is such as to render work impossible for long periods. To illustrate this, in constructing a day-beacon on this rock in five years only seventy days were sufficiently calm to permit work. The remainder of the time the weather was too boisterous to allow a stroke of work to be performed. The rock is completely submerged at high water, and is but little larger than the base of the tower, forty-one feet eight inches. The tower is one hundred and sixteen feet high, and solid from the base to the height of thirty-nine feet. The thickness of the walls at the doorway is seven feet nine and a half inches. Four keepers are employed to take charge of the light, and three of these are constantly on duty.

The off man is supposed to spend four weeks on the mainland with his family, but it frequently happens that eight weeks elapse before a landing can be effected. The difficulty of reaching the lighthouse and entering it is graphically described by Major Elliot, who visited it on his tour, and the description carries the conviction that the feat is one attended with no small hazard, as can be well understood from the engraving. The derrick employed for landing, except when in use, is taken down and fastened in deep channels in the rock; otherwise it would be swept away by the sea. The light is an excellent one, and gives out alternate red and white flashes.

The South Stock Light-house, at the extreme westerly point of Holyhead, the extremity of Anglese, is remarkable for the ingenious contrivance which has been adopted to obviate the drawback of its elevated position. A sliding light has been constructed, which is made to ascend or descend, as the exigency demands. By this means when the fog clouds hang over the land and obscure the light of the tower a light is run down to the foot of the cliff, and there gives warning to avoid the dangerous point.

In conclusion we cannot refrain from remarking that France and our own Government have done much to add security to commerce. In fact, the French nation to-day stands practically ahead of either England or the United States. We have merely selected the light-houses mentioned because they are the more striking of those found in Major Elliot's book. We regret, however, that the brevity of the article will not allow us to refer to some of the lights of France and other countries visited by him.

Axle Boxes.—Mr. J. A. Longridge, of Clapham, has patented some improvements in axle boxes for locomotive and other railway vehicles. The invention consists in dispensing with the so-called "rolling brass." Mr. Longridge makes the cheeks or flanges on the axle box in which the axle guides or horns work so as to present two convex surfaces to the axle guides or horns, instead of a parallel groove as hitherto, the narrowest part of the groove being in the centre line of the bearing, and widened out above and below.

—*London Mining Journal.*

ON THE MANUFACTURE OF BESSEMER STEEL IN BELGIUM.*

By M. JULIEN DEBY, C.E., Brussels.

From "Engineering."

The members of the Iron and Steel Institute of Great Britain were the first to promulgate the economic doctrine that it is more to the benefit of the manufacturer and of the trader in general to exchange freely the results of practice and of experience, than to lock up their proceedings from fellow-workers, and to live on hereditary secrets.

I am happy to have it in my power to affirm that this great idea, worthy of the century, is rapidly extending its beneficial influence beyond the contracted limits of the United Kingdom.

In America, Belgium, Germany, and even in France, most workshops of industry are now thrown open to the inspection of competitors, with a generosity which, a few years back, was quite unheard of.

As a slight proof of the truth of the above assertion, I come before you this day with a full statement of what our Bessemer Steel Works, in Belgium, are now doing, and of how they are doing it.

M. E. Sadoine, the able director of the John Cockerill Works, at Seraing, at my request, has given me full leave to divulge to the members of this Institute the whole of the results obtained at his new works, without any restrictions whatever, as to what I may communicate.

I shall, in consequence, proceed, in as few words as possible, to exhibit a condensed summary of the most important facts which I think may interest you.

At Seraing, the iron is most successfully and regularly run direct from the blast furnace into the converters—a most economical process, which, to my knowledge, has not, as yet, been put into practice in Great Britain, but which I believe ought to become universal.

Belgium lays no claim whatever to originality in the matter of this direct process. As early as 1857, the Swedish works had used it, and they continue to do so to this day, adding iron to the charge when the production of the furnace is insufficient. In 1863, the same process was introduced into the Styrian Works, of Turrach, and in 1864, into those of Heft, in Carinthia.*

In 1864, the Neuberg Company, in Styria, applied it also, and this Company, as well as that of Heft, have since that period considerably enlarged their works on the same basis.

In 1867, Terre Noire, in France, employed the direct run from the furnace, and, if I am not mistaken, the Creusot has also lately adopted the same principle.

The new steel works, at Seraing, constitute one of the most important departments of that extensive establishment. Very few in Europe, if any, are better organized at the present time for the economical transformation of iron ore into steel on a large scale.

The whole plant was devised, and the plans put into execution, by the combined efforts of two intelligent young engineers of the company, MM. Greiner and Philippart, to whose kindness I owe to have been able to examine minutely all details, and to have had access to official documents, from whence I have derived most of the figures contained in this paper.

The foundation-stone of the steel works of Seraing was laid in March, 1873, and on the 1st of February, 1874, the first blow was made in the Bessemer converters.

In order to simplify the subject, I shall proceed methodically and follow the ores in their successive transformation:

1. Into pig iron in the blast furnace.
2. Into steel ingots in the Bessemer converters.
3. Into rails, tyres, axles, etc., in the forge.

But, before doing so, I must give a short account of the plant and of its distribution.

* Read before the Iron and Steel Institute.

* These works were fully described as early as 1866, by M. Habets, of Liege, from official documents in the *Revue Universelle des Mines*, vol. xx., p. 273, where the advantages of the process were enumerated.

When the whole works are completed, they will comprise four blast furnaces (of which two are already finished) united by bridges, and between which are placed atmospheric lifts.

Each furnace is furnished with four Whitwell stoves placed in a square, forming thus two parallel rows of eight stoves each.

The principal dimensions of the blast furnaces are as follows:

	Metres.		Feet.
Diameter of hearth	1.60	=	5.248
" bosh.....	5	=	16.40
" top.....	3.50	=	11.48
Total height.....	18.50	=	60
Inclination of boshes.....	67½ deg.		

Capacity.. 225 cubic metres=7,942 cubic feet.

Three blast engines of the special vertical type of Seraing, so well known on the Continent, and of which 123 are now in operation in various places, furnish the necessary blast, at a pressure which attains 30 centimetres or 12 in. of mercury.

The blowing cylinders of the engines have a diameter of 3 metres, or 9.84 ft., and a stroke of 2.44 metres, or 1 ft. The steam cylinders are on the Woolf condenser principle.

The normal number of revolutions of the engines is 13 per minute. This furnishes 400 cubic metres, or 14,120 cubic feet of blast, the quantity needed for the combustion of 120 metric tons of coke in 24 hours.

To the right and left of the blowing engines are situated the mixing sheds for ore, and outside of these again are the pumping engines for the whole of the hydraulic apparatus of the establishment.

The sheds, where the charges of ore are prepared, are supplied with hydraulic lifts, which raise the ore to the proper height, and allow of its being thrown into separate boxes or compartments, where an intimate mixture of raw material can be easily effected.

In front, and to the north, is placed a group of boilers, made from Bessemer steel plate, 1.60 metres, or 5,248 feet in diameter, and 15 metres, or 49 feet in length. They each carry a large reheater 3.28 feet in diameter, and 49 feet in length below them. The boilers are heated by the escaped gases from the blast furnaces.

On the south side, the blast furnaces are situated alongside the Bessemer foundry, which is divided into three separate compartments by a series of cast-iron columns.

The first compartment comprises the pig bed, and also receives the ladles and the hydraulic lifts, which carry the molten metal from the furnaces to the converters.

The second compartment contains the cupolas, where the re-smelting of the pig iron is effected when at any time or from any cause it is thought advisable to work by the old process.

The third compartment comprises the converter compartment. Here we find six converters, two to each pit, receiving alternately the iron from the furnace or from the cupolas as the case may be, these last being furnished with hot air receivers for keeping the liquid metal hot.

Parallel with these buildings, and on the south side, are situated the blast engines for the converters, the pumps and the accumulators having, to the right and to the left, a group of eight boilers each, of exactly the same make as those employed for the blast furnace engines.

The Bessemer blast engines belong to the class constructed as a specialty by the Seraing Works, and were designed by M. Kraft, the well-known chief-engineer of the Cockerill Company, and whose name must also be honorably attached to the whole mechanical department of the steel works. These engines are of the compound vertical type, realizing a very great economy in fuel. The consumption of coal being only 1¾ kilogs., or 2¾ lbs., per indicated horse power per hour. We next come to the rolling mill, the length of which is 82 metres, or 270 ft., and which comprises two divisions, each 18 metres, or 59 ft., wide, and united by a row of columns 33 ft. in height.

In the first division are placed six large sized Ponsard and Bicheroux furnaces, whose bottom measures 4.50 by 5 metres, or about 12 ft. by 16 ft., and are sufficient to hold the ingots needed for the two rail mills situated in the next or third compartment.

The first, or blooming mill, has two pair of 30-in. rolls, and is actuated by a reversible engine running 45 turns per

minute by means of gearing. This has a separate engine for the condenser.

The steam cylinders are 32 in. in diameter, and have 4 ft. stroke, the pinions being in proportion of 1 to 2½.

The second or finishing mill, has two housings with 24-in. rolls, and is worked by a direct-acting reversible engine running 80 to 90 revolutions per minute. This engine has two steam cylinders 40 in. in diameter, and acts directly on a crank from 12 in. to 14 in. in diameter, placed on the axis at the end of the combination.

Special condensers are applied to this engine in order to avoid the inevitable counter-pressure so prejudicial to the working of engines of this class. As a complement to the rolling mill, a special rail-finishing shop is established, which will contain all the most modern and improved appliances for the purposes required. All the buildings of the works are simple, light, and airy, iron being largely used in their construction. They constitute a very harmonious and symmetrical whole.

I.—*Blast Furnace Practice.*

As an example of the working of the new plant, we cannot do better than transcribe the results obtained in furnace No. 1, during each week of the months of March and April last. These are as follows:

1875.	Coke.	Ore.	Limestone.	Iron.
	Metric tons.			
March 1 to 7....	417	759	211	370
" 7 " 14 ...	424	771	218	360
" 14 " 21....	415	773	183	369
" 21 " 28....	475	910	184	433
" 28 " Apr. 4	468	913	208	434
April 4 " 11....	459	869	198	449
" 11 " 18....	455	868	172	447
Weekly average ...	445	838	196	409

The mean composition of the charges was as follows:

Coke.....	1650 kilogs.	=3630 lbs.	Eng. avdp.
Ore.....	3100 "	=6820 "	"
Limestone.	725 "	=1595 "	"

The ores specially employed were Algerian and Spanish, and the mixture consisted of:

Water.....	6.50		
Carbonic acid.....	2.50		
Silica.....	15.00		
Alumina.....	4.00		
Lime.....	3.00		
Magnesia.....	1.50		
Oxide of iron.....	64.00.	...Iron	45.08
Oxide of manganese...	4.25.	....Mang.	3.00
Sulphur.....	0.10		
Phosphoric acid.....	0.075		
	99.925		

The practical product being 49 per cent. of pig iron.

The proportion of limestone added was 23.50 per cent. The coke was all made in Appolt ovens, and was very regular in quality, leaving from 8 to 10 per cent. of ash.

With the above mixture the iron obtained contained on an average:

Silicon.....	2.25
Carbon.....	4.50
Sulphur.....	0.04
Phosphorus.....	0.06
Manganese.....	3.75
Iron.....	89.40
	100.00

A considerable percentage of slag was produced. This slag is generally of a white color with a greenish tinge, and falls promptly to dust when exposed to the air. Its composition is as follows:

Silica.....	37.00
Alumina.....	13.50
Lime.....	43.00
Magnesia.....	1.50
Oxide of iron.....	0.59
Manganese.....	3.50
Sulphur.....	1.25
	100.25

The preceding figures show that the consumption of coke has never exceeded 110 lb. to the 100 lb. of iron produced. This good result is attributable to the great care taken throughout the whole of the metallurgical processes, and to the high heat, 600 deg. Centigrade, maintained in the blast.

It is also interesting to note what becomes of the reduced oxide of manganese which was contained in the charge of mixed ores. Of this, two-thirds are found in the pig iron and one-third go into the slag.

II.—*The Bessemer Foundry.*

The molten metal is, immediately it has run from the blast furnace into the tilt-ladle, taken to the converters by means of hydraulic lifts and the stationary bridge on which it is carried on rails. It is weighed in a very simple manner while on the lift, by means of the indications of an ordinary pressure gauge placed in communication with the water in the hydraulic cylinder of the lift.

No inconvenience is suffered if the iron be left for even one and a half hours in the ladle, beyond the presence of a small solid bottom, which can be remelted afterwards in one of the cupolas.

The whole operation of conversion of iron into steel lasts from 15 to 22 minutes.

In the middle of the decarburation, from 10 to 25 per cent. of rail ends are added, the quantity varying according to the temperature of the bath.

The most remarkable fact connected with the whole process at Seraing is that no spiegel whatever is introduced into the converter at the end of the blow, it having been found that the iron contained sufficient manganese to render this addition quite useless.

As soon as the bands of the spectroscope have all disappeared, the slag is essayed in a very simple and practical manner, the end of the operation being determined simply by a color test. The *modus operandi* is as follows: The blow is momentarily stopped and the converter inclined; a paddle is then introduced through the mouth and dipped into the bath. This is then drawn out, steeped at once in water, and the thin sheet of investing slag taken off and compared to a standard scale.

A lemon yellow slag corresponds to a very hard steel containing:

	0.75	of carbon or more.
Orange yellow.....	0.60	" "
Light brown.....	0.45	" "
Dark brown.	0.30	" "
Bluish black.....	0.15	" "

The small metallic globules imbedded in the samples of slag, and resembling blow-pipe beads, may also be tried by hammering them on a small anvil. A very short experience soon teaches the nature of the steel, by the degree of malleability of the globule. If too hard, it requires several blows of the hammer to form a small starred disc, by the splitting of the edges; if too soft, it flattens down at the very first blow of the hammer. These are two extremes to be avoided, unless for quite special purposes.

As soon as the metal in the converter has reached the desired degree of hardness, which, as we have seen, can be regulated at will, by prolonging or shortening the blow, it is run into the moulds in the usual way, and the ingots are taken to the forge as soon as crystallization has taken place, and before they have had time to cool.

Three very light hydraulic cranes to each pit lift out the ingots rapidly, and without any kind of difficulty. The pit itself is very wide, 10 metres, or 33 ft., in diameter, and is very shallow, only 0.90 metres, or 3 ft., deep, and the moulds being placed side by side, plenty of space is left for circulation in the centre.

The general distribution of the Bessemer foundry brings to mind the American works, and nowhere on the Continent, nor in England, does there exist any establishment where the practical facilities are greater, nor their results more economical, than they are here. Having visited nearly every steel-work in Europe, and many in America, I can speak with confidence in this respect.

At present, the production reaches 100 tons of ingots for each pair of 6-ton converters in 24 hours, but this figure will be largely increased when the new rail mills are finished, and rails of two or three lengths are rolled at once.

The economy realized by the direct run from the blast furnace is easy of calculation. It consists in a reduction in the quantity of iron used, added to a saving in fuel, and to a diminution in labor.

Since iron has been run from the new Seraing blast furnaces, not a single case of black slag has occurred, which gives sufficient proof that the iron produced is fit for the manufacturer of first-class steel.

A very remarkable fact, as yet quite unexplained, is the undeniable one, that the direct product of the blast furnace works better in the mill and gives much tougher steel than that obtained by the

resmelting of the same iron in the cupola.

The chemical composition being identical, the steel from the direct process has stood the ordinary tests for rails and tyres much better than that which has been obtained from the cupolas.

III.—*The Rail Mill.*

Until the present day, the ingots have been taken to the old rail mill, and rolled into single length rails. Even here, the advantages and economy of rolling the ingot while still hot have been fully appreciated. A very ordinary mill produces, in this case, 600 tons of 20 ft. rails, weighing above 70 lb. to the yard, per week.

No doubt whatever can be entertained that the new mill, now in course of erection, and which will work ingots two or three times heavier than at present, will turn out 1,200 tons per week without any difficulty.

As it takes 30 hours for the conversion of iron ore in the blast furnace into pig iron, and as the operation in the converter lasts about one hour, including carriage of ingots, handling, etc., and assuming that after one hour of heating the rail may be rolled; we confidently affirm that, in the short space of 36 hours after the arrival of the ore at the works, a rail may be ready for shipment, and during the whole process the material will not have been allowed to get cool.

This appears to me about as complete a solution of the problem of producing steel direct from the ore as has yet been proposed by many of the ingenious searchers of the day.

WATER SUPPLY AND DRAINAGE.*

By W. A. CORFIELD, Esq., M.A., M.D.

I.

It will be our purpose in this course to discuss, in the first place, the sources and the kind of water that are required for large communities—the kind in the first place, the quantity in the next, the places to get it in the third, and then the ways to convey it to the community.

It is only one part of the fuel of a community that we have to consider. We shall then consider what are the wastes from a large community, and whether, although useless for the purpose for which the original fuel was supplied, they can be made useful for other purposes, and if so, how? Whether again there is any necessity of getting rid of them, and if so, how this can be done most effectually, and most cheaply, and without prejudice to other communities.

Now then as regards water. Water is required in a large community for a great variety of uses. These uses were divided by the Romans, and they have been divided ever since, into public and private uses. The public uses are such as for cleaning streets, extinguishing fires, for fountains, for public baths, and so on. The private uses are for drinking, washing, cooking, etc. Thus water you see at once from the mere examination of its uses comes to the community to be soiled. It comes in order that the community may be supplied with one of the necessities of life. It comes to wash communities, places, and habitations. It comes, I repeat, to be soiled. It is, therefore, generally, when soiled, useless for the purpose it was originally wanted for. It has either to be purified or got rid of. A community requires pure water for some purposes, and those are especially for drinking and cooking. Pure water—I do not mean chemically pure, but we shall see directly what is meant hygienically by pure water—is not necessary for every purpose such as for washing the streets, extinguishing fires, etc. However, practically speaking, only one kind of water can as a rule be supplied to a community, and so it becomes necessary for us to know where we can

* Abstracts from a course of lectures delivered before the School of Military Engineering at Chatham, England.

get this sufficient supply of water of a certain quality, viz., sufficiently good for drinking.

Now, roughly speaking, a drinking water should be, in the first place, transparent. In the second place, it should be transparent to white light: that is to say, it should be transparent and without color. It must be without taste and without smell, and it must deposit no sediment on standing, and have no particles suspended in it. Those are the rough qualities of water which anybody can examine for himself; the best way to look at it is to look through about a foot or 18 inches of it in a long glass cylinder, placed on a piece of white paper. It must be aerated to be fit for drinking, and cool. Now, if the water you are examining does not fulfil these conditions, it must be rejected at once, or brought to satisfy them. We have to consider how these conditions are to be fulfilled, and we ought to satisfy them on a large scale. But a water may comply with all these conditions, and yet not be a safe water to drink. It may contain substances which you cannot tell in any of these ways, and practically speaking, all waters do. Substances whether in solution or suspension may be hurtful, or they may be harmless, and now I want to tell you how, if you have a chemical analysis of a sample of water before you, you can tell whether that water is suitable for your purpose or not. That is a thing you do not generally find in engineering books. It is necessary for you to know it, because if a report is brought up upon a particular water, you ought to be able to know whether that will be a satisfactory water or not.

Natural waters contain dissolved (in the first place especially) carbonic acid gas. They contain all the constituents of air in solution, but the gases are not in the proportion in which they are in atmospheric air. There is often a great quantity of carbonic acid gas, and oxygen being more soluble than nitrogen is generally in larger proportion than in atmospheric air. Now the carbonic acid gas is the one that I am going to speak of first. Water containing carbonic acid in solution has the property of holding in solution quantities of certain salts that it would not dissolve otherwise, or only in much smaller quantities, and the chief of these is carbonate of lime. Natural waters often contain then, in the first place, salts of lime, especially the carbonate, dissolved in carbonic acid. They contain often the sulphates of lime, soda, magnesia, iron, and so on—in fact, different salts of these and other bases. Phosphates they all contain, and also chlorides and nitrates. All natural waters contain the latter in certain proportions—even rain water. Almost all of them contain salts of ammonia. The question arises which of these may be allowed in water, and which may not, or which, at any rate, may not be allowed above a certain quantity, and what is the quantity? Beyond those simple characters for pure water which I gave you a few minutes ago, there is a property of natural waters which can be easily ascertained by any one, and which constitutes one of the best known differences between various specimens of water, and that is the quality of hardness. What does that mean? Hardness is tested in this way. Pure water dissolves soap, which is a combination of soda with some of the fatty acids. Pure water dissolves soap perfectly and forms a lather at once. Now water containing certain salts in solution, and notably salts of lime, magnesia, and iron, does not do so, because these salts form insoluble precipitates with the soap. That is what is meant by the water being hard. If a water, instead of lathering with soap immediately, takes a great deal of trouble to make a lather, does not do it till after some time, and causes a curdy precipitate, then it is a hard water. That is, of course, a very rough way of putting it; but the amount of soap that is required before a water will lather, gives a test of the amount of salts which cause the hardness of the water, and the chemist takes a standard solution of soap and tries how much of this solution is required before he can get a lather with water, and he says that the water has so many degrees of hardness. What is meant by a degree of hardness? That each gallon of the water contains in solution an amount of salts which will precipitate as much soap as a grain of carbonate of lime would precipitate. What is the importance of this? Hard water is as a general rule less wholesome than soft, and often much less so, it is not so

good for household purposes, nor for use in engines, and it entails an enormous waste of soap. It is therefore objectionable, even if the hardness is caused by the presence of harmless salts. The total amount of hardness, the degree of hardness of a water before anything is done to it, is called the "total hardness," and if the total hardness of a water is greater than six degrees on what is called "Clark's Scale" (the value of a degree of which I have already explained) it is called a hard water; if less, it is known as a soft water. Now hard water (supposing you have only got hard water, and cannot get a supply of soft water) is made softer, in the first place, by boiling. That can be done on a small scale. If you boil hard water, of course the carbonic acid is driven off, and the salts held in solution by it, especially carbonate of lime, are precipitated. There is another way of rendering hard water soft, and this can be applied on a large scale; it is known as "Clark's process." The carbonate of lime is held in solution in the water by carbonic acid; you can precipitate it by boiling, or prevent its being held in solution by causing the carbonic acid to combine with something else, as with more lime, and Clark's process which is now used on an extensive scale (and ought to be used very much more than it is) consists in adding to the hard water milk of lime. This milk of lime combines with the excess of carbonic acid, forming carbonate of lime, which falls down as precipitate together with the carbonate of lime that was previously held in solution, thus leaving the water softer. If you boil water, and then determine the hardness that remains, that is called the "permanent hardness;" an extremely important matter. The importance of it consists in this, that it cannot be removed at any rate on a large scale, and, in the second place, that it is due to salts several of which are injurious, so that a large degree of permanent hardness indicates a bad water. Now this permanent hardness (the hardness that is lost by boiling is called "temporary hardness") is due chiefly to the sulphate of lime and chloride of calcium, and to magnesian salts. These are all objectionable in a water. Let me give you some examples of degrees of hardness of various specimens of water so as to give you a definite idea of hardness.

The hardness of the Thames water above London is 14 degrees of Clark's scale. That is a hard water. The hardness of the New River water is 15½ degrees. That, too, is a hard water. The water of Bala Lake has only ¼ of a degree of hardness, and of course that is an exceedingly soft water. I must tell you before going on (because it is very likely that you may take up one of the Registrar General's Reports and see what he says about the water supply to London) that it is now very usual to express hardness in another way. That is to say, instead of saying so many grains per gallon as is done in Clark's scale, hardness is now very generally expressed by parts in 100,000, and I mention this at once, because the results of most of the analyses that we shall have to refer to during the lectures are given in parts per 100,000. Of course, if you are given the hardness of water in parts per 100,000, you can convert it into degrees of hardness in Clark's scale by multiplying by seven and dividing by ten, because Clark's scale gives the results in grains per gallon; a grain per gallon is one part in 70,000. On this new scale, as an example, the hardness for the last week of last year of the five Thames companies was about 20 degrees, that is to say, about 14 degrees by Clark's scale.

The hardness, again, of the water supply which is derived from deep borings in the chalk was 29.4 on this scale, or 20.58 of Clark's scale. Of course that is a very hard water indeed. But the hardness of these two waters is quite different, because the permanent hardness of Kent water is very little indeed. The total hardness of that water is almost entirely due to the carbonate of lime, whereas, much of the hardness of the water supply to London by the Thames companies is due to salts other than carbonates, especially to sulphates. Therefore, you get much information about the quality of water by its hardness. If you know water has a high degree of permanent hardness, you know it has a very good chance of being a bad water. It contains probably sulphate of lime and chloride of calcium, and perhaps magnesian salts. The latter are

especially objectionable to water, and any water which gives even a small amount of salts of magnesia is to be rejected. Water containing these salts causes diarrhœa when drunk, and it appears to be from the presence of these salts in drinking waters that the swelling of the neck known as *goitre* is produced in Switzerland and other countries.

The next thing to which I wish to draw your attention with regard to substances dissolved in water, is, the amount of chlorides that may be present. I may say broadly, that if you see in a report on the quality of a water that it contains much chlorine, or much common salt (chloride of sodium), you may at once put it down as a suspicious water, and you will see why in a minute. Where do you get chlorides in a water? They may come from an infiltration from the sea. They may come again from strata containing a quantity of common salt. But another source of chlorides in a water is pollution by sewage. All sewage contains a considerable proportion of common salt. This is one of the necessities of life, it is contained in many of our foods, and in excretal matters, especially in the urine, and so sewage contains it. The average amount in the sewage of water-closeted towns is ten parts of chlorine in the 100,000. Pure natural waters contain less than a grain of chlorine in a gallon, or about 1 part in 100,000. So, if in a sample of water for which you get the analysis sent, you see more than a grain in a gallon of chlorides, you must at once know the reason why. London drinking water contains 2 parts in 100,000. That is not very bad water, and as it is got from the Thames we know that it has been polluted by sewage. The water derived from the chalk—the Kent water—actually contains more than that, but we have a very good reason for not objecting to it on that account, inasmuch as we know that it is not rendered impure by sewage. The well waters of London mostly contain more chlorine than sewage, they are in fact, a concentrated form of sewage which has gone through certain alterations. I am not here alluding to the Artesian Wells, but only to those which are supplied by the subsoil water above the London clay. The amount of chlorine is a very good test of the purity of a water, except that you must always allow for the possibility of chlorides being present in the soil through which that water has gone.

Nitrates and nitrites are given you in the Registrar General's Reports as the test for what is called "*previous sewage contamination.*". What does that mean? It means that the nitrates, &c., that are dissolved in water come in a great majority of cases (if not in all) from the oxydation of organic matter at some time or other, or in some place. Now to show you how plain it is that water must not be rejected merely because it contains nitrates, I must tell you that there are nitrates and nitrites in all waters, even in small quantities in rain water. What amount of nitrates may be found in water without giving a suspicion of previous contamination? Allowing that they are not injurious in themselves, yet, inasmuch as they at once make you suspect that the water containing them in solution has, at some time or other, been contaminated with organic matters to a large extent, which organic matters have been oxydized, the result being the production of nitrates and nitrites; inasmuch as that is the case, if you get much nitrates, &c., represented in a water, you must at once see if that water is derived from a source where it is likely to get contaminated with refuse matters; because if it is, although the nitrates are harmless, and although it is very desirable that these matters should be oxydized to that state, still you are always liable to its happening some day that the water is contaminated by the solution of these organic matters in their crude unoxydized form, in which case they are very often, if not always dangerous. Let us see what amount of nitrates is found in various waters. In the drinking water we get in London from the Thames there are about 2 parts in a million (or 0.2 in 100,000). In the New River Water (North London water) a little more than 3 parts; and in the Kent water 4 parts in a million, so that the deep chalk waters (which we know must be very pure) contain more nitrates than the others do, a sufficient proof that the presence of nitrates is not of itself a sufficient reason for rejecting a water. The waters from the Cumberland Lakes contain very much less. To

give you an example of a water containing a great deal, I may cite the instance of a well at Liverpool which was found to contain more than 8 parts in 100,000 of nitrates and nitrites, which were all derived (or in all probability derived) from the oxydation of sewage that had traversed the ground round that well. If nitrates be present in large quantities it must be regarded as a suspicious circumstance, unless you have good reason to know that the water comes from a source which is beyond the suspicion of contamination. There are quantities of nitrates in many soils. The presence of nitrates in water got from such soils would not justify you in having the water condemned as a source of supply if there were no other reason.

Salts of ammonia. These, too, are contained in natural waters in exceedingly small quantities. They do no particular harm in themselves, but they frequently come directly from sewage. The numbers in a drinking water representing salts of ammonia ought to be in the third place of decimals for parts in 100,000, or if in the second place of decimals ought to be small. Now the water supply of London, filtered Thames water, contains .001 to .005 parts in 100,000. That is pretty good. The water at Bala Lake contains .001 parts, and rain water contains the same amount; so that we may expect salts of ammonia to be contained in all natural waters. Sewage contains about 6 parts in 100,000. Well water often contains large quantities, four parts for instance; the pump water in London contains nearly one part in 100,000, and the water of the Thames at London Bridge 0.1 part in 100,000; these are all bad waters, so that when you see ammonia mentioned in an analysis of water in greater quantity than is represented on the second place of decimals in parts per 100,000, you may always safely condemn it, for on looking further you will find what I am now going to speak of, namely, organic matters.

Now the actual organic matters present in a water may be in suspension or solution. If there are organic matters in suspension a water may be safely condemned, because they may even by agitation pass into solution, and so the fact of your trying to separate them may cause more of them to get into solution. Organic matters you will find in analysis represented in two different ways. In one, as for instance in the analysis given by the Registrar General, you will find organic matters represented in this way: so much organic carbon, and so much organic nitrogen in the 100,000, and the Rivers Pollution Commissioners have given this as a standard, not of drinking water, but of a water that shall be considered to pollute any water course to which it is turned. Two parts of organic carbon in 100,000 or 3 parts of organic nitrogen in 100,000. What does the London drinking water contain again? From 3 to 4 in 100,000 of organic carbon (I take this from the Registrar General's reports), and about .05 of organic nitrogen. Now we shall see at once the difference between drinking water derived from such a source as the Thames and filtered, and drinking water derived by boring into deep strata—into the chalk. The chalk water only contains .06, that is the fifth of the quantity of organic carbon, and .01, a fifth of the quantity of organic nitrogen that the water supplied by the Thames Companies contains; so that when you come to organic matters, you see the difference at once between a water that is derived from a pure source, and one from an impure. The other method that I have to mention to you, which is used for expressing the amount of organic matters in water, is called "Wanklyn's method" from the chemist who discovered it. This method consists in the conversion of the nitrogen contained in the organic matter in the water, or a considerable part of it, into ammonia, and then it is estimated as so much ammonia. I dare say you all know that the test that chemists have for ammonia is perhaps the most delicate test with which we are acquainted. This ammonia you will see mentioned in the records of analysis as "albuminoid ammonia," and to a certain extent it does represent the amount of organic matter in the water. This albuminoid ammonia in a drinking water must not be allowed to be above the third place of decimals. If it appears higher than the third place of decimals in parts of 100,000, if in the second place, or if in the first, it is bad. If in the first place it is decidedly bad water, and contains a considerable amount of organic

matter in a state of solution. You may consider that the albuminoid ammonia represents about ten times its weight of dry organic matter, and about forty times its weight of moist organic matter. So that .05 of albuminoid ammonia in 100,000 represents about 2 parts of moist organic matter in the water. You see that when you have an analysis of water before you, you must consider the different things together. The nitrates help to condemn a water with much organic matter in it. The ammonia does the same, and the chlorides especially so, and chlorides are to be regarded as a suspicious indication in water, if you have not good reason to suppose that they come from some other source than the one I have indicated. The danger of organic matter in drinking water consists in this fact (of course organic matters are necessary to us for our food, and it is not the mere fact of its being organic matter that renders it dangerous) that it is organic matter in a state of rapid change; in a state of putrefactive change, and then that it may contain, and often does contain (especially if it is derived from excremental matter) the poison of specific diseases, which may be distributed in the drinking water to a population and cause an outbreak of cholera, typhoid fever, etc. We know now what sort of water must be got for drinking. The above are its characteristics, and the water supply must either comply with these conditions, or be made to do so artificially.

Now how much of it is wanted? You can look at this in two ways. You can get to know by experience how much bodies of men and towns always have wanted. The amount, of course, varies immensely with the use of baths, whether they are public baths or not, with the amount used for washing the streets, and for manufactures, and also with the amount of waste, because that is a very important item. Now, for washing, drinking, and domestic purposes generally, you may put it down (if there is reasonable amount of bathing) at about ten gallons a head a day, and then you must add nine or ten more for flushing the sewers and washing the streets. Much of this will be added through the water-closets. Thus you may say 20 gallons a day without waste may be taken as a kind of average. For trades you must allow 10 gallons more as a rule. If there are public baths, and where there are many animals, as horses, which require about 12 or 15 gallons a head for washing and drinking, you must make a greater allowance. You will see that about 30 gallons a head a day is the least even where there is no extra demand, and that is about the amount provided in London, and that is about the least that you should aim at. Professor Rankine tells you that 35 gallons is the greatest amount necessary. However, they don't think so everywhere. New York manages to get through 300 gallons, and does not find it too much. In ancient Rome (to show you that these matters have been thought of a long time ago) they had nine aqueducts to bring water to the city. They thought it of so much importance that several of these aqueducts were from 42 to 49 miles long, and one of them, the Marcian, was 54 miles long. Frontinus, who was the superintendent, and who wrote a most excellent work about them, giving accurate descriptions and measurements of them, tells us the two most recent were made because the seven already in existence "seemed scarcely sufficient for public purposes and private amusements." Now the sectional area of the water supply to Rome by these aqueducts was 1120 square feet, and it is pretty sure that there were not more than 332,000,000 gallons daily brought to Rome by them. I suppose there were not more than a million people; that gives you about 332 gallons a day that they found necessary.—(Mr. James Parker on the "Water Supply of Rome.")

Now, let me give you one or two points about the measurement of water that you will find useful. The measurement of water you will often find given in cubic metres. A cubic metre is 35¼ cubic feet or 220 gallons. That is to say, a cubic metre of water is 220 gallons, and as a ton of water contains 224 gallons, a cubic metre of water is almost exactly equal to a ton by weight (or tun by measure). A cubic foot is rather more than 6 gallons, and 100 gallons are just about 16 cubic feet. Let me just give you an example of this. London during December, 1872 (I find from

the Registrar General's report), was supplied daily with 100 millions, nine hundred thousand, and something odd, gallons of water. That is to say 458,577 cubic metres, or about the same amount of *tons* by weight or *tuns* by measure; that is, 201.8 gallons to each house, or rather less than a cubic metre to each house, and 28.4 gallons to each person. I told you it was 30. Well it varies a little. It is a little under 30 very often. Of the total amount of water supplied to a place, you may take it as a general rule that 80 or 82 per cent. is required for domestic purposes, so that during that month of December in London, there were about 23⅛ gallons used for domestic purposes. Hence the conclusion about the quantity is, that the least you must endeavor to get is 30 gallons a head a day without any very extra demands. Of this about 80 per cent. will be required for domestic and the rest for public purposes.

So much for the quality of drinking water, and the quanty to be supplied. We have now to go on to consider the places where water of this quality and in sufficient quantity can be procured. The main sources of water are rain, and the sources that are subordinate to rainfall—wells, springs, streams and rivers. Some other sources which are used occasionally, and which are of very little use for a great supply, are such as the dew, ice, snow and distilled water. These latter we may dismiss with a word or two as only of exceptional utility. Dew has been used in deserts and at sea. Ice and snow furnish enormous quantities of water in certain places where they abound. Ice furnishes an exceptionally pure water, because in freezing the salts are separated out, and the gases too; such water therefore requires aeration. Snow and ice if used should not be collected near to dwellings, because of the risk of contamination. Distilled water is an important water supply now, especially at sea. Its chief fault is that it requires aeration. To give it this Normandy's apparatus may be used, or it may be allowed to fall from one vessel to another like a shower. It has been said that cases of lead poisoning have occurred at sea "partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition," (Dr. Parkes.) So much for the subordinate sources, which are all of little importance to us.

We now come to rain, which is the original source of all great supplies. Rain, which we are going to consider, is, of course, caused by the fact that when two air currents come together, both saturated with moisture one having a lower temperature than another, the mixed air, though it has a mean temperature, has not the mean capacity for water, but a capacity less than the mean, and so some of it falls as rain. Is rain, as it falls, sufficiently pure to be used as a source of drinking water? In the first place it is very soft. In the second place it is well aerated. It dissolves especially carbonic acid and oxygen from the air—the former being about three per cent. of the total dissolved gases, and the latter from 30 to 40 per cent. It contains nitrates and nitrites, especially during thunderstorms. It contains salts of ammonia, which render it more alkaline when collected in the country. Near towns it contains most of the impurities that are found in the air of towns, and especially it becomes acid instead of alkaline, absorbing a large amount of the sulphuric acid that is in the air. It contains organic matter, and this in increased amount near towns. Rain half a mile from the extreme south-west of Manchester, although the wind was blowing from the west, tasted flat, insipid, oily and nauseous—deposited organic matters, and even organized bodies in considerable quantities, and left a clear water above, containing more than two grains of organic matter in the gallon. Dr. Angus Smith, who examined this water, makes the following remarks: "It becomes clear from the experiments that rain-water in town districts, even a few miles distant from a town, is not a pure water for drinking; and that if it could be got direct from the clouds in large quantities, we must still resort to collecting it on the ground in order to get it pure. The impurities of rain are completely removed by filtration through the soil; when that is done, there is no more nauseous taste of oil or of soot, and it becomes perfectly transparent." He is therefore of opinion, that rain collected directly from the air cannot, at any rate near to towns, afford a proper

water supply. However, since rain is the source of all the supplies that we get, it becomes necessary and of great importance in estimating the amount of water that can be got in a district to measure the rain-fall of that district. Now the depth of the rain-fall of a district has extraordinary varieties, both as to place and time. For instance, as regards time, the tropical rain-fall is almost all at one part of the year. With us it is variable. The rain-fall is measured in England by its depth in inches. The rain-fall is greater in mountainous districts, and on the leeward side of mountains, if they are not high enough to penetrate the clouds, but if they are, it is on the windward side, because the clouds do not get over the tops of the mountains. Now, for the supply of water, the important points to be known about the rain-fall are these. The first is the least amount of rain that has ever been known to fall in a year in a district; the minimum annual fall. Then it is important to know the distribution of the rain throughout the year, and especially the longest drought, because you have got to provide for that time as well as for any other time, and the observations on the rain-fall of a district should extend over not less than 20 years. Of course it is not often that you can get observations at any locality that have been maintained for 20 years, and so we shall have to consider in an instant or two how we are to get over that difficulty.

The machine used for measuring the depth of rain-fall is called a rain gauge. It is essentially a funnel, the area of the top of which is known very accurately. The top of this funnel is provided with a vertical rim to catch the splashings so that none may be lost. Below the funnel there is a glass vessel placed to receive the water. The height of the water in it may be indicated by a float, or its quantity may be ascertained at given intervals of time by measuring or weighing it, and that is the best plan. Of course the number of cubic inches of water, which is the same as the number of square inches of the area of the funnel, gives you one inch of rain over that area. Suppose the area of your funnel it 20 square inches, 20 cubic inches of water will obviously be the result of one inch of rain-fall over that 20 inches. It is most convenient to measure the water, and the measuring glass is constructed in the following way :—At the place where that amount of cubic inches of water stands which is equal to the number of square inches in the area of your funnel a line is drawn, and this represents one inch of rain-fall. If the area of your funnel is 20 square inches, then you take 20 cubic inches of water which you have weighed or measured accurately, place it in your glass vessel and mark *one* at the level where it stands, because that amount is equal to a depth of one inch of water over the area you are observing One cubic inch of water weighs 252½ grains, almost exactly. That one inch is divided into tenths and hundreds ; and with this vessel you are able to measure the amount of rain that has fallen through the funnel in a given time. The top of the gauge must be placed nearly level with the ground ; the instrument must, in fact, be sunk. It must be placed in an open situation, and a fence put round it if necessary. One is very frequently placed at a height above the ground, and one on the ground to show the difference in the amount of rain that falls at the two levels. The amount of rain that falls at the level of the ground (leaving hills out of the question) is always greater than the amount that falls at any height above the ground. If you have got records of the rain-fall of a district for a considerable number of years your work is to a great extent done, because then you have merely to take out the facts that you want. If you have not, the only way to do it (with a limited time) is to place rain gauges at convenient situations, and as many as possible all over the district you are examining, and if there are any hills in or near the district some of them ought to be placed on their tops, and each of these rain gauges ought to be carefully and regularly examined at certain fixed times. Then you must compare the records of all these gauges with the results given by the nearest rain gauge that has been observed for a considerable number of years, to get a kind of relation between the rain that falls at these different stations on your district, and the rain that falls at the nearest place from which you can get any re-

liable data, and from this comparison you must calculate what will probably be the longest drought in your district, and what is probably the least annual rain-fall. Now, the average in different parts of England is from 22 inches to 100, or even 120 per annum; in some countries, as Burmah, 180 to 220, and it is even said to be as much as 600 inches in one place. This useful rule was given by Mr. Hawkesley (and certainly the tables show that it is a very accurate rule) that if you take the average rain-fall of a place for 20 years, and substract a sixth from it, that will give you the average annual rain-fall of the three driest years during that period. If you take the average annual rain-fall for 20 years, and take a third part from it, that will give you the amount of rain in the driest year of these 20 almost exactly, and if you take the average of 20 years, and add a third to it, then that will give you pretty nearly the amount of rain in the wettest year.

So you get with a considerable amount of accuracy the quantity of rain; the least amount of rain you are likely to get, and the greatest as well. Then, of course, you want to know the area of the district, and besides the actual amount of the rain-fall, you must also know the amount which is available. In the first place, a great deal of the rain-fall is lost by evaporation and absorption. Evaporation from the surface, and absorption by plants, &c. Then, if the ground is very porous to a great depth, a considerable amount will be sbsorbed so fast that you cannot collect it. Most of the rain-fall is at once available from or near the surface in steep countries, and especially those which are formed of primitive and metamorphic rocks, as granite, clay-slate, &c., and generally from impervious rocks that are steep-sided. Almost all the rain-fall in these cases is available at once. It runs off the surface and collects in lakes, and is available directly. And then, on hilly pasture lands in limestone and sandstone regions, something like two-thirds of the rain may be considered available, and on flat pasture countries something like one-half. For instance, on the green sand, Mr. Prestwich estimated that from 36 to 60 per cent. is available. On chalk and loose sand there is very little indeed available.

Now one of the most important things, if *not* the most important thing to know, is the geological character of the rocks of the district you are examining, because that will tell you a very great deal about the amount of available water, and about the way to get it. We are told that in chalk countries the rivers and streams carry off at once about a fifth of the rain-fall; that the evaporation and absorption by vegetables and animals amounts to as much as a third, and that the remainder (*i.e.*, the greater part of the total rain-fall) sinks into the ground. In less absorbent strata you may put down that it is about equally divided—that one-third is carried off by the streams, &c.; another third absorbed by plants and animals, or lost by evaporation, while a third sinks into the ground.

Well now, let us consider what means have been taken to get at this water that sinks into the ground. Of course it is got at by digging down, and now we must consider in what strata we are likely to be successful in digging wells or making borings to get underground water. In the first place, wells in sands lying over impervious strata, over clays especially, if they are not deep, do not, as a rule, afford much water. They may, however, afford a fair supply as to quantity, but very often afford a bad supply as to quality. For instance, the wells sunk into the sands and gravels over the London clays afford a very impure water. If water of this description has come directly from the surface, and especially in the neighborhood of towns, it is contaminated in all sorts of ways. The water in these wells never overflows or spouts up. Wells, on the other hand, sunk through impervious strata to pervious ones below, generally, though not always, supply excellent water. At any rate, they have much greater chance of supplying excellent water, because they supply the water that has come from the high grounds at a considerable distance. For instance, the borings that are made through the London clay down to the chalk, supply some of the best water in London. The Kent water is still better, and is supplied in large quantities by borings which pass through the chalk, through the upper green sand, and through the gault (an impervious stratum)

into the lower green-sand. These wells are known as Artesian wells. The water rises up a considerable height in them, and may overflow. It is often thought that Artesian wells always overflow, but they don't. The water rises up to a certain height, which height is of course determined by several considerations,—for instance, by the height it came from originally. Of course the water that you get from under Kent is the water that has fallen upon the outcrop of the green sand at a very considerable distance round the London basin.

Mr. Prestwich, who has paid the greatest attention to the water supply of London, and to the arrangement of the strata around London, has calculated that, from the lower green-sand underneath the London basin, there is to be got an enormous supply of water for the metropolis, that is to say, on the presumption that this lower green-sand is continuous underneath London. It would not be fair if I did not tell you here that the lower green sand does not appear to be continuous underneath the London basin. Some of the older strata are brought into contact with the chalk, so that the lower green-sand is missing, probably, underneath a great part of the district. This we know from deep borings which have been made at several places. Of course the chalk and also the green-sand are merely instances. You want to know the alternation of the strata right away down the whole geological series, so as to be able to say, if you go into a country and study the maps and sections for a short time, "If we make a well here and bore down, we shall probably go through a band of clay into a pervious stratum, and get a supply of water." You want for this purpose to study the geological maps, and to have ample time to do it. If we go below the chalk into the oolitic series, we have similar alternations of pervious and impervious strata. When we go below this we come to the new red sandstone, and I mention this, because there is an important point connected with it. The new red sandstone is (to a great extent) a pervious stratum. It contains enormous quantities of water, but the caution about it is, that in many countries it holds immense salt deposits. It is in the new red sandstone of Worcestershire (for instance) that the salt deposits of Droitwich are found; so that borings in the new red sandstone (although it is true that some towns are supplied from that stratum), are frequently found to give a brackish water. Below this come the Permian strata, in which you have the magnesian rocks, that I mentioned last time, and it is a mischievous thing to bore into these strata, because you may get water containing large amounts of magnesian salts. Towns which are placed upon these strata are best supplied (like Manchester) from older formations, such as mountain limestone, and so on, which generally afford excellent water. The best supplies are obtained from them, not by boring or by wells, but from springs. There is one thing I must mention, before I leave the wells, and that is, that the sinking of deep wells may lower the level of the water in the country above considerably, and that is a point that has often to be taken into consideration. For instance, Mr. Clutterbuck showed that wells at a considerable distance from London have been seriously affected by the pumping of the green-sand water below London. He showed that the level of the water in these wells was affected so much, that you could tell by the levels of the well waters at a considerable distance from London, whether the pumping had been going on in London on the previous day or not. There is another thing that requires to be known, especially about borings in the chalk, and that is, that some of the borings will give an inexhaustible supply of water, practically speaking, while borings close by will give you next to none. This Mr. Prestwich accounts for, by stating that the water in chalk runs chiefly through crevices, and does not infiltrate through the mass of rock. Before I say a few words to you about the construction of wells, I have something to say about springs, and the amount of water they supply. Now springs occur where you have an impervious stratum cropping out from beneath a pervious one, and this may happen in various ways.

The water in springs, and also that in wells, varies very much in quality according to the place that it is taken from. Spring water differs from rain water in that it has passed through certain rocks,

and dissolved more or less considerable quantities of substances on its way. Spring water resembles rain water in containing a considerable amount of carbonic acid in solution. This has the property of dissolving many substances, one of the chief of which is the carbonate of lime. The water then passing through the rocks dissolves carbonate and sulphate of lime, salts of iron, &c. It is important to know this for many reasons. In the first place, some of these waters dissolve, in mountain limestone districts for instance, so much carbonate of lime as to become what is known as petrifying springs. Of course if you take a petrifying spring and bring it along an acqueduct, under certain conditions your supply is stopped up: and one of the acqueducts at Rome is to be seen to this day perfectly closed for a considerable length with a deposit of carbonate of lime and other salts, because the contractor took in a spring that he was not told to tap—a mineral spring. Now the purest spring water you can get comes from the igneous, the metamorphic, and the older stratified rocks. Many of these hard rocks yield a very pure water without a great deal of salts in solution. The mountain limestone, the oolitic limestones, and the chalk rocks also yield a good supply, and these waters are fit for drinking so long as they do not contain any quantity of magnesian salts. Water from sandstones, especially the new red sandstone, I have told you, often contains common salt. Waters in clay countries very often contain considerable quantities of the sulphate of lime. The waters of the London and Oxford clays do, as also the water of the lower lias clay. These are bad waters. They are permanently hard and unwholesome. Well waters have partly the same qualities, unless they contain additional impurities from the causes I have mentioned before. River water is often purer than spring water; that is to say, it often contains less total solids in solution. The permanent hardness is generally greater. It contains less substances in solution, because much of the carbonic acid has escaped, and the substances it held in solution have been deposited. River water very often contains much more organic matter, especially near towns.

Wells sunk in hard rocks may require no lining at all; if they pass through sandy strata they require a lining of brickwork, and sometimes part or the whole of it must be set in cement. For an artesian well, an ordinary well is dug first of a tolerable breadth and depth, and then a boring is made which varies from twenty down to three or four inches in depth. As soon as an impervious layer is bored through, and a pervious stratum reached, the water rises through the boring into the well (which acts as a sort of cistern), and has to be pumped up, or it may rise so high as to overflow.

The ordinary atmospheric lifting pump is seldom used, but a kind of lifting pump with a solid piston and metallic valves is often used. In fact, the cylinder in which the solid piston slides is connected with the space between the valves above the piston instead of below it. So that when the piston is raised the water is lifted through the upper valve, and when it is depressed water is drawn from the well into the body of the pump through the lower valve. Forcing pumps are also used. They are driven by engines, and the water is pumped into air vessels, by which the pressure on the mains is equalized so that it does not come in jerks. Let me mention one or two examples of artesian wells, and the amounts of water got from them in different strata. From the well of Grenelle, near Paris, in 1860, there were about 200,000 gallons daily. This well when first sunk yielded 800,000 gallons daily, so that you see the supply has considerably diminished with time, which is an important thing to take note of. The boring of this well of Grenelle began at twenty inches in width, and ends at about eight or somewhat less. It is 1,800 feet deep (being one of the deepest borings ever made), and more than 1,700 feet of it is lined with copper tubing, which was placed there instead of some wrought-iron tubing, with which it was originally lined. The copper tubing begins at 12 inches in diameter and goes down to 6½. The temperature of the water in this well at about 1,800 feet is as much as 82 F., and you may put it down that as a rule, the temperature of the water increases 1° F. for every 50 feet below the surface. Of course there

are certain places where it increases very much more (about Bath for instance), but these are exceptional cases. The boring in the well at Trafalgar-square is sunk 384 feet from the surface into the chalk, and it yields 65 cubic feet in a minute, or more than 580,000 gallons in the 24 hours. There is a well in Woolwich in the chalk 580 feet deep, which yields 1,400,000 gallons in 24 hours, and the last I am going to mention in the chalk is a well near London—the Amwell hill well—close by the source of the New River. That is only 171 feet deep, and it is said to yield very nearly 2½ million gallons in the 24 hours. (Hughes on "Waterworks.") As all this water underneath the London basin comes originally from districts at some distance from London, it is not to be wondered at that the pumping at London lowers the level of the water in the wells in those districts. These are examples of successful borings. Now, a word with regard to the new red sandstone wells of Liverpool. These wells you will find described in the twelfth volume of the proceedings of the Institution of Civil Engineers. One of them called the "Bootle Well" has many points of interest about it. Its maximum yield was, in 1853, about 1,100,000 gallons in the 24 hours. A curious point about it is that at the bottom of the well instead of there being one boring there are 16 or 17. These 16 or 17 borings are of very different depths, and it became very interesting to know whether the whole of them were of any use, and Mr. Stephenson thought of blocking them up, all but one. He did so, and found that one yielded very nearly as much water as the 16, so that a very considerable amount of capital had been wasted in the boring of these holes. That is worth knowing. There are six other public wells at Liverpool in this new red sandstone, and the ordinary yield was about 4½ million gallons daily from them all. This was in 1850. Eighteen years afterwards, evidence was given before the Commissioners on the Water Supply for the Metropolis of a falling off in the water supply of these wells. In fact, the continual pumping had diminished the supply. In 1854, these wells in the new red sandstone at Liverpool were pronounced failures by Mr. Rawlinson, as also were others in England and America, and Mr. Piggott Smith, in a report on the water supply of Birmingham, confirmed this, and it is a fact that they have had to be supplemented by a supply of much superior water from a distance. Mr. Stevenson estimated the cost of a pumping station for one of those Liverpool wells, including shafts and steam engines, at £20,000, and the annual cost per million gallons a day at £1,324, this being without interest or compensation, but including depreciation. Generally, well waters are liable to vary in amount from month to month, and from year to year, as witnessed by the amounts pumped from these Liverpool wells, and by the amounts pumped year after year from the Cornish mines.

After wells, the next thing we have to consider is the way in which water can be collected from springs and streams over a large area, called a drainage area. That is one method of supply, and the other method, of course, is pumping from rivers. We tell the amount of water that can be got from a large surface of land, in the first place, by a way I spoke to you about before, viz:—by estimating the amount of available rainfall on it. Then we can tell it in another way, by correctly measuring the amount of water that is brought down by streams and springs; so that we have to consider the methods used for gauging springs, streams, &c. The gauge most commonly in use is the one known as the Weir gauge. Weir gauges are made by damming up the stream, and making it all pass over a sharp ledge or through an orifice or notch, or row of notches, on a vertical board. Then from formula you can, by means of tables, calculate the amount of water that passes through the notch, or over the orifice of the weir in a given time. You determine the height of the still water by means of a scale, the zero of which is level with the base of the notch, and you do it in this way. A stick is planted in the bed of the stream, its top at some little distance from the weir, and so that its top is level with the base of the notch, or row of notches, in the weir, and then you measure by the scale from the top of this stick to the level of the water from the orifice. That is one way. The next plan is by calculating from the declivity.

This is only applicable to regular channels, like the New River for instance, and if the stream is small you can make the whole of it pass through a trough, and then calculate the velocity from the declivity. Another way is by measuring the maximum surface velocity, which is done by means of floats of any sort, or by means of fan wheels, and various little instruments for measuring the surface velocity of streams. You take the maximum surface velocity, and about three-fourths of this will represent the mean velocity of the section. The discharge of springs is estimated by the time taken to fill a vessel of known capacity. A word about the permanence of springs and streams, which is an extremely important point. In the first place you must try and get evidence from maps and trustworthy sources generally. At the bases of hills springs are usually permanent. In flat countries you may put it down that the reverse is generally the case. Springs in limestone countries are very permanent. Springs in very permeable strata are very generally variable, unless they are tapped at a considerable distance from the surface, and then they often give an enormous yield.

Springs in primary strata, and in granite countries are very often very permanent indeed, and it is in these countries you have some of the large lakes which are used for supplies of water. In clay basins the water supply is variable as a rule, being very great in the winter, when there are often floods, and very small in summer. In chalk countries the springs are more permanent, for the reason that they draw from considerably beyond the actual basin. Intermittent springs sometimes occur, especially in the chalk; they are due to the gradual collection of water in subterranean hollows, which when filled above a certain level empty themselves by means of a syphon shaped outlet; it is obvious that they must not be relied on as sources of a supply of water. This will end our consideration of the merits of different localities from the water supply point of view.

THE IRON ORES OF SWEDEN.

By Mr. CHARLES SMITH, Barrow-in-Furness.

Journal of the Iron and Steel Institute.

Although the iron trade of Sweden is on a very small scale compared with that of England, the quality of much of the metal manufactured is of so high a character, that the subject has an importance far beyond the mere question of the quantity produced. In round numbers, England makes twenty times as much iron as Sweden; the Furness district alone producing more iron and iron ore than the whole of the latter kingdom. Notwithstanding this comparative insignificance in quantity, the Swedes, with their wonderfully pure ores, have succeeded in manufacturing iron which, in many branches of trade, appears for the present to be a necessity, and which is perhaps the finest in Europe. On these considerations, I hope that a brief account of the Swedish iron ores may prove not uninteresting to many members of the Institute.

The iron ores of Sweden are, with an insignificant exception, of one class; and though they vary considerably in their iron percentage, and to some extent in other constituents, they have a very great external similarity. The ore is either Magnetite or Red Hematite, containing every percentage of metallic iron, from 30 per cent. to almost chemical purity, which, for the former would be 72, and for the latter 70, per cent. The hematite, called "bloodstone," gives the same streak as the English red hematites, but is externally scarcely distinguishable from the magnetite; both kinds are named in Swedish "Mountain ores;" they have a slightly different aspect from the Spanish and Algerian magnetites, but possess nearly the same blue-black color.

A small varying quantity of Brown Hematite is procured in the south of

Sweden, from the large bogs of Smaland; and in winter a similar ore is dredged from the bottom of certain lakes in the same province. The average of this ore would probably not exceed 25 per cent. metallic iron, though it occasionly contains 50 per cent.; frequently it is so intermixed with sand as to be of little value; phosphoric acid is generally present, sometimes up to 4 per cent.; manganese is often a constituent, and in a few places has a strength of 20 per cent. The yearly quantity raised of this ore is as varied as its composition; in 1855, it was 12,000 tons; in 1860, 20,000 tons; in 1866, 8,000 tons; in 1867, 17,000 tons; in 1869, 6,000 tons; in 1871, 15,500 tons; in 1872, 12,000 tons.

The other ores of iron, with trifling exceptions, do not occur in Sweden. The red and brown hematites and the oolitic ores, such as those we have in England, are absent altogether; chalybite, the white carbonate, is found in hand specimens in a few of the metalliferous mines; and a thin insignificant bed of argillaceous iron ore has been met with in the Skane coalfield.

Judging from official returns, the average yield of the "Mountain" ores, throughout the kingdom is under 50 per cent. metallic iron. In 1872, from 671 mines, 718,000 tons of ore were raised, and 333,000 tons of iron manufactured; but of the former, 12,000 tons were bog and lake ores, with very low percentages, and about an equal quantity of the "Mountain" ores was exported to Finland. Besides the iron oxide, the main constituent of the ores is almost invariably silica. Lime, magnesia, and alumina are generally present; the last usually in the smallest quantity. Phosphorus has rarely a greater strength than 0.05; though in some ores, not worked, upwards of 1 per cent. is found; and it sinks to 0.004 at Persberg, and to 0.003 at Dannemora. Sulphur, with a few marked exceptions, is not generally present to a much greater extent than phosphorus.

The surface of Sweden is mainly covered by plutonic rocks, of which granite is the most abundant, although large areas are occupied by gneiss, mica slate, and every variety of porphyry; there is also a felspathic rock peculiar to Sweden, termed "Helleflinta," or Leelite, which, though small in quantity, is of great importance in reference to iron, as this metal is nearly always present where Helleflinta occurs. Over a vast area, in these granitiferous rocks, iron ore is found in greater or less abundance; though, doubtless, the iron districts are still most imperfectly known, as so much of the country, especially in the north, is for iron-making purposes inaccessible. Far in the north, beyond the head of the Gulf of Bothnia, the iron deposits of Gellivara are probably the richest in the world; but the rigor of the long winter has, hitherto, prevented any commercial success in the working of the mines; and, according to the Government returns, the annual production does not reach 50 tons of ore. More to the south, a few small mines are worked, but only on the most limited scale, until the parallel of Gefle is reached. We may, perhaps, assume that future research will prove that Sweden possesses the greatest stores of her purest ore in her most northern provinces; but we can scarcely hope that these can be made available, without changes in value taking place that, at present, cannot be anticipated. In the southern portion of the kingdom very little ore is raised. The main bulk is obtained from the central provinces. The counties of Kopparberg and Orebro alone produce 50 per cent., and Westmanland and Wermland 30 per cent. of the whole yield.

Iron ore is by far the most important Swedish mineral. The "Mountain" ores occur in veins, which are sometimes regular, but more generally are deflected from a straight line, and occasionally even form a semicircle. Usually they have a north-east to a south-west direction, though north to south and east to west veins occur. Their width varies from mere strings up to, as at Schyss-hyttan, 200 feet. Probably 30 to 50 feet would be the general strength of the veins now worked. In some instances, these can be traced for some distance along the surface; but, commonly, they dip down at a steep angle. As so many are known, few have been thoroughly explored as to their depth; when worked to 200 or 300 feet deep, other shallower veins have been started, except in the more important deposits.

The mode of formation is, as yet, an unsolved problem. Many difficulties present themselves in opposition to each of the more popular solutions. The veins are occasionally found in gneiss; at other times in granite; but, generally, they are separated from their granitic surroundings by a band of Helleflinta, which is usually only present in small quantities; but at Persberg, the largest mine in Sweden, the surface for two miles in one direction is composed of it. In some cases, the veins descend perpendicularly; and in at least one instance (at Persberg), the vein, after so doing, makes an elbow at right angles and lies horizontally.

It is commonly believed that the ore is an aqueous deposit, probably from hot water. Though numerous facts support this theory, many will not coincide with it; perhaps the chief being that there is not the slightest external appearance of the ore being a water deposit, as it is in solid irregular masses, lying in equally solid rock, which in those cases where granite overlies is unquestionably plutonic. Assuming that Helleflinta is an altered clay, which has by no means been proved absolutely, and that both it and the ore were deposited simultaneously, there would be some mechanical mixture of the two, and not the perfect demarcation that exists. If the ore were an aqueous deposition, it must necessarily have been, at some time, horizontal; and whatever the convulsions were, which could, as in the Persberg instance, tilt up one end of the vein to the extent of 90°, they could not do this without a great dislocation of both the vein and the surrounding rocks, whether it happened before or after the solidifying of the ore and the Helleflinta, and this is not the case.

In certain instances the iron oxide is found interspersed in grains for some distance on either side of a vein, which becomes more and more rich as it approaches the centre, where is the purest part. It is difficult to account for this on any ordinary aqueous or ingenious theory.

The peculiar magnetic properties of much of the "Mountain" ore offer little assistance to the solution of the problem of its formation. The magnetite and hematite are found closely intermixed, the one highly magnetic, the other not affecting the needle; the ores being similar in appearance and constituents. Some masses of magnetite are much more magnetic than others, affecting the compass through 20, or even 50, fathoms of intervening rock; whilst to some bodies of equally true magnetite, the needle will not dip, though not more than 10 fathoms of rock intervene.

In several districts, especially in the Norberg mines and, to a less extent, in those near Nora, the ore has a very singular striped appearance, caused by numerous veins, or nearly parallel layers, of crystallized quartz lying amongst the ore.

May I be allowed to suggest that, perhaps electricity may have been the chief agent in the formation of these mineral deposits. It is difficult to understand in what possible way they could be formed by volcanic action; and it appeared to me to be equally impossible to understand how these veins of iron ore, which dip steeply over immense areas of country, could owe their origin to water, without exhibiting some trace of aqueous deposition; especially when their centres are the purest part, whilst they gradually on either side pass imperceptibly into the surrounding rocks. It seems still more difficult to account, either by the aqueous or igneous theory, for the finely veined ores of Norberg, which consist of thin parallel layers of magnetite and crystallized quartz. But what might be difficult or impossible for fire or water to accomplish, might perhaps be effected by electricity, if we assume that currents may have acted, in definite directions, for long periods of time, segregating the particles of iron oxide, which exist in a slight percentage throughout vast masses of many Swedish rocks.

Although there is so strong a similarity amongst all the Swedish "Mountain" ores, there is generally a sufficient divergence, in chemical composition, to give a separate character to most of the districts, and to some of the individual mines.

Pre-eminent for its purity is the best Bispberg ore, which contains up to 70 per cent. metallic iron, or almost a chemically pure oxide; only a small proportion reaches this high standard, the bulk

of the output varying from 50 to 60 per cent. The mines, which are thirty miles south-east of Fahlun, claim an antiquity of 600 years; they are very small, producing under 15,000 tons per annum. On account of the purity of the ore it is much esteemed as a mixture, but from the isolation of the mines it becomes very expensive to most of the works which use it. From the working drawings, it does not appear as if the production could be much increased. The greatest depth is about 700 feet, with the vein, which lies in quartz and talc-schist, dipping steeply.

Much the largest iron mines in Sweden are those at Persberg, near Filipstad, in Wermland. The veins, of which the largest is 66 feet at its greatest width, lie altogether in Helleflinta. The deepest workings are over 600 feet below the surface, the largest 400 to 500 feet. The annual production has lately been between 50,000 and 60,000 tons. The ore rarely contains less than 50, and rises to 60 per cent. metallic iron; it is much valued for furnace purposes, for its purity and freedom from deleterious ingredients; it commands a higher price than that from any other large mines, and, to a great extent, the iron ore market of that part of Sweden is regulated by its selling price. Persberg is said to have been worked for 800 years.

The most famous of the Swedish iron mines are those at Dannemora, in Upsala County, away from the main iron districts. The annual production is under 25,000 tons, and has varied but little for over 20 years. The ore contains from 25 to 60 per cent. metallic iron; very little has over 50 per cent., and the average is much below; most contains sufficient lime and silica to be smelted without a flux; it has also about 2 per cent. manganese. The highest percentaged ore does not make the best pig iron. The mines have been worked steadily for four centuries; the largest is in three sections, the centre, an open-work, being the chief. The main vein is somewhat irregular; it has an average width of 100 feet, being 150 at the widest, and has been explored 900 feet in length in the open-work, which is 200 feet wide, with walls, either perpendicular or slightly overhanging, of over 500 feet in vertical depth. The bottom of this extraordinary mine was covered, during my visit in the month of August, with large blocks of ice. The veins lie in Helleflinta, of which there are several varieties; different trap rocks are present, with granite and gneiss. The production of the mines might be greatly increased, but they are held under a tenure that prevents more than a certain quantity being raised. The ore is never sold, but goes solely to the furnaces of the different joint proprietors. The largest owner is Baron De Geer, the representative of a Dutch family, who, in the 17th century, aequired a practical monopoly over the iron trade of Sweden; most of their works and mines have passed into other hands, but they still retain Lofsta, where is manufactured, from Dannemora ore, the L iron, the dearest in Europe of its class.

A new railway will shortly open up the Grangesberg district, in Dalecarlia, which, it is considered, may prove the most productive in Sweden. At present the mines are cramped by expensive transit. The ore in the most southern part of the district is of very high quality, and free from phosphorus; but this ingredient increases regularly in a northerly direction, until in the extreme north the ore is of little value.

The mines round Norberg, in Westmanland, produce about 70,000 tons per annum of ore, which contains from 45 to 50 per cent. metallic iron. The striped appearance of this ore, caused by fine layers of quartz amongst the iron oxide, is peculiar. Notwithstanding its large percentage of silica, it makes good iron. The veins are from 20 to 50 feet wide, and lie in gneiss, but are separated from it by bands, on either side, of Helleflinta. About three years ago, a new ore was discovered here, containing 35 per cent. iron and 20 per cent. manganese, which it was hoped might produce spiegeleisen; but it is understood that the experiments have not been successful.

In the neighborhood of Nora, in Orebro County, there are many mines; those at Striberg are second only to Persberg in production; but the ore is the poorest in the district, with only 48 to 50 per cent.; whilst at Dalkarlsberg, which is the deepest iron-mine in Sweden—about 800 feet—the best ore has 68 per cent.

metallic iron, and very much rises to 60 per cent. Much of the Nora ore contains manganese; at the Wickers mines up to 9 per cent. The manganiferous ores almost always contain mundic (sulphuret of iron); in some cases they have to be calcined twice to drive off the sulphur; they are also much more close-grained in appearance than ordinary magnetite, and some becomes brown with two or three days' weathering. Many of the Nora veins are red hematite, which rarely contains over 55 per cent. metallic iron. Some of the magnetic veins have been proved over a thousand yards in length.

For the Bessemer steel trade, by far the most important mines in Sweden are those at Schysshyttan, 10 miles from Smedjebacken, in Delecarlia. The ore is a mixture of magnetite and knebelite; the latter, a very rare silicate of manganese and iron, met with at Dannemora and a few other localities, but nowhere, except at Schysshyttan, in any quantity. The combined minerals contain 50 per cent. iron and manganese; they produce, without the addition of any other ore, the highest class of spiegeleisen. The vein, which has more the appearance of a lode, can be traced along the surface for a considerable distance; it is 200 feet in breadth, and has been proved to 300 feet in depth, without any appearance of the bottom; the centre of the lode is the best; at the edges the ore is not good.

Far to the south of the general iron district, near Jönköping, in Smaland, is the remarkable hill of Taberg. As far as has been ascertained, this hill, which rises 380 feet above the level of the surrounding country, is a solid mass of close-grained serpentine, containing on the average about 30 per cent. metallic iron, and which is in appearance very like some of the hematite ores of the north. Two sides of the hill are perpendicular, and form quarries, whence has been taken for years the supply of ore for a dozen furnaces, which altogether have only an annual production of 3,000 tons pig iron. This iron has been found well suited for a few purposes, and is very tough; but the demand is limited. The heavy percentage of magnesia in the ore has hitherto been an insuperable obstacle to any large manufacture. Were this difficulty overcome, this hill would be one of the most valuable iron mines in the kingdom.

The foregoing are the chief representative iron mines in Sweden, either for quantity of production, or quality of ore. All the mines are much alike in character, with the exception of Dannemora partly and Taberg wholly, as the mode of working is almost identical. In some cases the veins of ore come to the surface; but generally they are discovered by a magnet of peculiar construction, so made that the needle can dip as freely as turn horizontally; as soon as these magnets come over a body of magnetite, the needle swings round and points downwards to the mineral. When the presence of the ore is ascertained, a large hole is usually made down to the vein, which may be worked open for a short time, but as most dip at a steep angle, the ore is mainly obtained by mining. As the walls are solid, only a trifling amount of timber is used, often none at all. The surrounding rocks are so firm, that it rarely happens any are brought down by the constant blasting; the only one that I saw, during a lengthened tour through the Swedish Iron districts, which had given away, or become unsafe, by the rock crushing, was at Guldsmedshyttan, in Orebro County. The whole of the "Mountain" ores, without any exception, have to be blasted. The small shafts, that may have to be sunk through overlying granite drift, are frequently of very rude construction, bound round with withes and, if not round, of no regular shape. The drainage of the mines gives much trouble; except where steam is unavoidable, hydraulic power is always used, and often the pumps are worked by bobs of immense lengths.

Royalties in Sweden belong half to the landlord and half to the discoverer of the mineral; but the former may take half the mine, if he elect to do so. On finding any deposit, in the case of iron by magnet or otherwise, an application is made to a government official, termed bergmaster, who grants a certificate of ownership, should no adverse claim be presented and proved within a given time. These bergmasters, of whom there are ten, have each a separate district, the whole kingdom being divided amongst them. They have very consid-

erable power, and appear to settle almost all mining disputes.

The value of the iron ores varies to a great extent, depending not only on chemical composition, but also to a very great degree on local position. It must be remembered that the key to the Swedish iron trade is not the mineral, but the fuel, supply. This latter has been annually growing in relative importance, until lately it has become the chief particular. Charcoal still remains, notwithstanding the importation of foreign coal and coke, the main fuel of the country; and as it deteriorates most materially in transit, the fuel supply determines the locality of most of the Swedish works. Often ore is carted 20 or 30 miles, or transported over 100 miles by road, canal, and railway; whilst furnaces have been built in Finland, where there is but little native ore; or in the Hernosand district, up the Gulf of Bothnia, where there is scarcely any, to save carriage on the charcoal. The ore in this way has, often to bear a most burdensome carriage, and its cost varies for every works. As far as possible, the annual supply is laid in during the winter, as it is more cheaply transported over the snow and ice, than by road in summer. Many furnaces are dependent on a hard winter for obtaining any supply at all; and such during a winter like the past mild one, when there was scarcely any snow, are obliged to be blown out. When the furnace proprietor raises his own ore, the cost varies probably from 3s. to 16s. per ton, delivered at the works; and some of the best ores are worked the cheapest. Norberg ore, with 50 per cent. iron and much silica, is quoted about 16s. per ton, delivered at Stromsholm, on the Malar Lake, where sea-going vessels can load. Ordinary ores, with a little over 50 per cent. iron, are sold in Wermland and in the Nora district, at about 27s. per ton, delivered on the railway or at some mining centre. Persberg ore would be more expensive, and is quoted on a sliding scale according to percentage. Dalkarlsberg ore, when containing 68 per cent., is quoted over 30s. per ton, delivered on the railway. The majority of these ores would have to bear heavy carriage in addition to these prices, which are from 50 to 100 per cent. higher than in 1871.

In conclusion, I have only to regret that this sketch does so little justice to the subject undertaken, but I shall be satisfied if it has enabled the members of the Institute to obtain a clearer perception of the marvelous resources in iron ores possessed by Sweden. At present the iron trade in that country is cramped by want of fuel, labor, capital, and means of transit. But every year now should lessen these deficiencies, and we may, perhaps not without reason, look forward to a not distant future, when the iron trade of Sweden will be of European importance, not alone from the quality, but also from the quantity, of the metal produced.

ELEMENTARY DISCUSSION OF STRENGTH OF BEAMS UNDER TRANSVERSE LOADS.

By Prof. W. ALLAN.

Written for Van Nostrand's Engineering Magazine.

I.

In the following discussion the ordinary cases of loaded beams are treated without resorting to the higher mathematics. It is an attempt to compile from various sources the simplest methods of treating such cases as arise most frequently in practice.

Transverse stress is produced by a load applied to a beam in a direction perpendicular, or inclined, to its length. AD

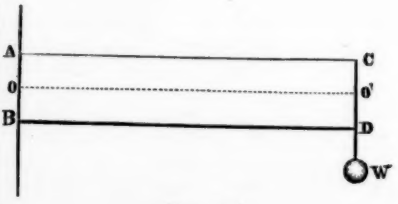

Fig. 1.

(Fig. 1) is a beam subjected to such a stress.

In this kind of stress a compression of the particles or fibres on one side of the beam, and an extension of those on the other, are produced. In consequence of this the beam *bends*. Experiment shows that the amount of compression on the the one side, and of extension on the other, diminishes as we go inwards from the top or bottom towards the centre, and at some intermediate plane, O O′, becomes zero. The fibres at this plane being neither lengthened nor shortened, it is called the *neutral* plane, and its intersection by the plane of vertical section is called the *neutral line or axis*. Experiment also shows that, from this plane towards the top and bottom, the amount of extension and compression may, for the stresses that occur in ordinary practice, be considered as varying directly with the distance from the neutral plane.

The extreme top and bottom fibres suffer the greatest compression and extension, and in case of rupture, the rupture begins with them. Some question exists as to the exact location of the neutral line or plane, but for slight deflections it passes through the centre of gravity of the cross section of the beam, and it is very probable that it never deviates from this position.

In discussing transverse stress, the assumptions based upon experiment may be stated as follows :

1. The forces on the fibres are directly as the amount of extension or compression they produce ; (*Ut tensio sic vis,*) and since the extension and compression increase as the distance from the neutral axis, the forces vary in the same proportion.

2. Within *elastic limits* the extension and compression at equal distances from the neutral axis are equal, and the forces producing them are equal.

3. The *neutral axis* passes through the centre of gravity of the cross section.

RECTANGULAR BEAMS.

Let us now discuss the relations existing between the forces in, and on, transversely loaded rectangular beams, the load being supposed to be vertical in direction and the beam horizontal.

Case I.

Let A D (Fig. 2) be a beam so thin that it may be considered as composed

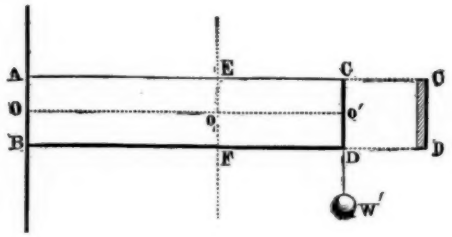

FIG. 2.

of but one layer of fibres or particles. Let it be fastened in a wall at A B, and be loaded with W′ at the other end. Neglect for the time the weight of the thin beam itself, which is small. Imagine it to be cut by a vertical plane E F at any point, and let us see under what forces the part E D is held in equilibrium.

The only external force on E D is W′ acting at D downwards, and E D is prevented from falling under this weight by the *resistance of the fibres* at E F. To analyze these forces, let us take O_1 as an origin of coordinates, and $O_1 O'$ as the axis of x, and $O_1 E$ as the axis of y, and as the forces are all in one plane, find their components along these axes. The *internal* forces, or resistance of the fibres at E F, are :

1. The *horizontal forces* which are tensile above and compressive below, and which increase from zero at O_1 just in proportion as we go from that point

towards the upper or lower edge of the beam. (Fig. 3.)

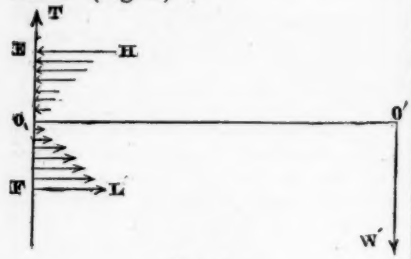

FIG. 3.

2. The *vertical force.* This is called the *shearing force*, or *transverse* shearing force. It resists the tendency of the part of the beam E D to slide down on the surface E F. The existence of this force may be realized if we conceive the beam to be divided into two parts by the vertical plane E F, and those parts to be united by some very elastic substance, as india-rubber. Then the beam would take the form shown in Fig. 4, the part F C sliding down on the other. The force in the beam that resists this sliding is represented in Fig. 3, by the vertical

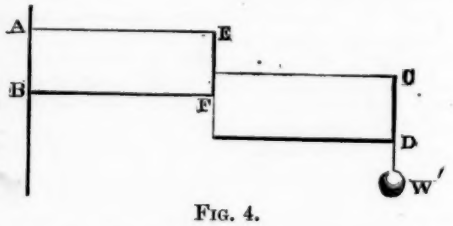

FIG. 4.

arrow at E. Let it be called T. In Fig. 3 are represented all the forces we have to deal with. Since this system of forces is balanced, the following equations must be fulfilled:

$$\Sigma X=0 \quad \Sigma Y=0 \quad \Sigma M=0 \qquad (1)$$

That is: the sum of all the horizontal forces (ΣX), and the sum of all the vertical forces (ΣY) must each be equal to zero, and the sum of the moments about any point as O_1 must also equal zero.

The only horizontal forces in the system are the two triangular groups of forces E O_1 H and F O_1 L, representing the sum of the tensile and compressive stresses on the fibres. As the group E O_1 H acts in a direction opposite to that of the group F O_1 L, and as the algebraic sum of the two groups is zero ($\Sigma X=0$), the groups must be equal to each other. This is indicated in the figure by the equality of the triangles E O_1 H and F O_1 L.

The vertical forces are W′ and the shearing force T at E F, and since

$$\Sigma Y=T-W'=0. \qquad \text{We have}$$
$$T=W' \qquad (2)$$

Next obtain the moments of all the forces about O_1 and place the sum of these moments = zero. Replace the

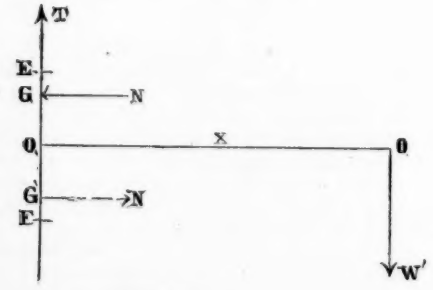

FIG. 5.

tensile and compressive forces by their resultants. The resultant or sum of all the tensile forces represented by the triangle $E O_1 H$ (Fig. 3) may evidently be represented by the area of the triangle of which the base $E O_1$ is the distance over which the forces are distributed, and the altitude $E H$ is the stress in the outside fibre. Let

$$S = \text{this stress} = E H$$

and $d = E F = \text{depth of beam}$

Then area $E O_1 H = \frac{1}{2} S d = N$ = resultant of tensile forces. Similarly

Area $F O_1 L = \frac{1}{2} S d = N'$ = resultant of compressive forces.

These resultants will pass through the centres of gravity of the triangles $E O_1 H$ and $O_1 F L$, since the little forces of which they are composed are represented by these triangles. Hence the direction of N will intersect $O_1 E$ at a point G (Fig. 5), whose distance from O_1 is $= \frac{2}{3} E O_1 = \frac{2}{3} \cdot \frac{d}{2} = \frac{d}{3}$. This is the lever arm of N about O_1. That of N' is $G' O_1$ also $= \frac{d}{3}$. Hence the sum of the moments of these two forces about O_1 (since they both tend to produce left-handed rotation) is

$$-N \frac{d}{3} - N' \frac{d}{3} = -\frac{1}{6} S d^2$$

The force T since its direction passes through O_1 has no lever-arm, and hence its moment is zero.

If the distance from O′ to O_1 be called x, the moment of the weight W′ is $= + W' x$ (since it tends to produce right-handed rotation)

$$\therefore W' x - \frac{1}{6} S d^2 = \Sigma M = 0$$

$$\therefore W' x = \frac{1}{6} S d^2 \qquad (3)$$

So far we have considered a beam whose breadth is that of only one row of fibres, but a beam of any breadth may be made up of a number of such slices placed side by side, and if b = the number of slices, or breadth of the beam, and W = the weight hung at the end of it, then eq. (3) becomes

$$W x = \frac{1}{6} S b d^2 \qquad (4)$$

This discussion is general and will apply to any section as well as to E F. S and x are the variables in eq. (4), and these quantities will have different values at the different sections, which values increase as we go towards A B (Fig. 2), but the form of the equation will evidently be unchanged. If A C (Fig. 2) be $= l$, we have for the section at A B (Fig. 2)

$$W l = \frac{1}{6} S b d^2 \qquad (5)$$

A B is the section of greatest stress, and the beam if overloaded will break there.

The quantity $\frac{1}{6} S b d^2$ is called the *moment of resistance* of the fibres, or moment of the internal forces, and is often written M for brevity. Wx is called the moment of the weight, or moment of the external forces. Let the maximum value of $\frac{1}{6} S b d^2$ (eq. 5) be called M_0.

We may illustrate geometrically the variation of the moments $M = W x$, and consequently of the stresses produced on the outside fibres from A_1 to C.

In Fig. 6 let A C be the beam. Take

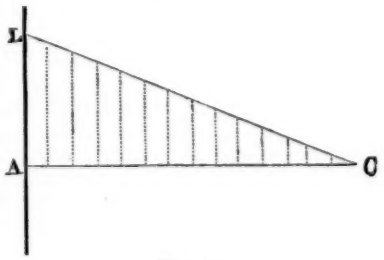

FIG. 6.

a line on some scale to represent the value of $M_0 = W l$, and lay it off from A perpendicular to A C. Let A L be this line. Draw L C. Then the dotted perpendiculars in the triangle L A C will represent the moments of resistance in the beam at the several points at which they are drawn.

From eq. (2) it is seen that the shearing force is constant at every section of the beam. This force we may assume with sufficient accuracy, for our present purpose, to be uniformly distributed over

the cross section of the beam on which it acts. Hence if A = area of cross section, and t = shearing force on a unit of the surface,

$$T=W=A\,t \qquad (6)$$

Lay off A C (Fig. 7) $=l$ and C P=W. Then the rectangle A P represents geometrically the shearing stress at every point of the beam.

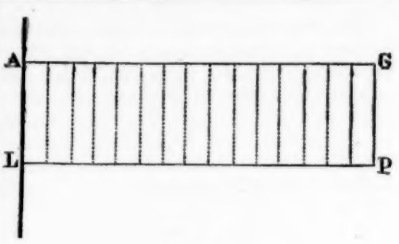

Fig. 7.

Corollary. When several weights as W W_1 W_2 (Fig. 8) are suspended from

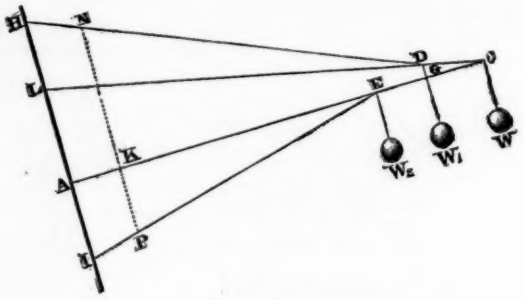

Fig. 8.

the beam at different points, the moment of resistance at any point is equal to the joint moments of the weights at that point. Thus, calling distances measured from C, G, and E towards A, x, x_1 and x_2 respectively, we have for the equation of moments for points between C and G

$$W\,x=\frac{1}{6}\,S\,b\,d^2 \qquad \text{Between G and E}$$

$$W\,x+W_1\,x_1=\frac{1}{6}\,S\,b\,d^2 \qquad \text{While at K,}$$

for instance, it is

$$W\,x+W_1\,x_1+W_2\,x_2=\frac{1}{6}\,S\,b\,d^2 \qquad (7)$$

The shearing force at K is

$$T=W+W_1+W_2 \qquad (8)$$

Geometrically. Let A C (Fig. 8) $=l$ A G$=l_1$ and A E$=l_2$. Lay off A L=W l, L H=W_1 l_1 and A I=W_2 l_2. Draw the triangles as in Fig. 8. Then N P=total moment at K, for instance.

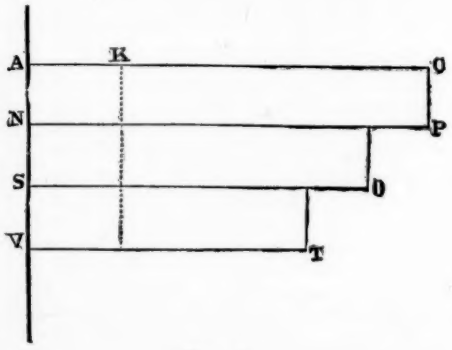

Fig. 9.

The shearing force is represented by the rectangles A P, N O, and S T (Fig. 9), and at any point in the beam is equal to the sum of the weights between that point and C.

EXAMPLES.

(1.) Suppose the safe stress per square inch to be 1,000 lbs. (= S), and $l = 10$ ft., $b=3$ inches, and $d=12$ inches, what weight will the beam support?

(2.) Suppose $W=\frac{3}{4}$ ton, $l=12$ ft., $b=2$ inches, what must be the depth (d) of a rectangular cast iron beam, so that S shall not exceed 4 tons?

Case II.

Let the beam be as in the last case, but with the load distributed uniformly over it (Fig 10). Let w=weight on a

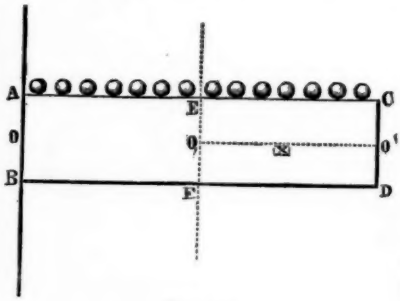

FIG. 10.

unit of length, W=total weight on A C, l=A C=length, d=A B=depth, x=E C as before. Then the forces to be considered are represented in Fig 11, the little arrows along E C representing the weight distributed along the beam.

Replace the weights along E C by their resultant, which is $= wx$, and which should be applied at the middle point of E C, since the little weights on the beam are uniformly distributed. Then putting the resultants N and N′ in place of the tensile and compressive force, and proceeding as before, we have

$$T - wx = 0$$

$$T = wx \qquad (9)$$

Also $$wx.\frac{x}{2} - \frac{1}{6} S b d^2 = 0$$

$$\frac{wx^2}{2} = \frac{1}{6} S b d^2 = M \qquad (10)$$

At A B (Fig. 10) these equations become

$$\left.\begin{aligned} T_0 &= wl = W \\ \frac{wl^2}{2} &= \frac{Wl}{2} = \frac{1}{6} S b d^2 = M_0 \end{aligned}\right\} \qquad (11)$$

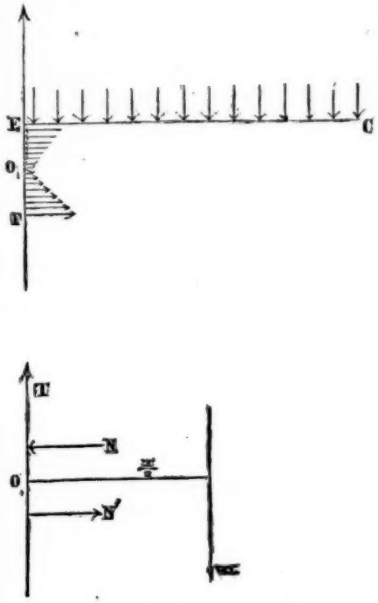

FIG. 11.

By comparing the last equation with eq. (5), we see that if the weight and beam be the same the stress on the fibres in this last case is only *one-half* what it was in the former, or, what amounts to the same, the beam will bear twice as much distributed over it, as it will when the weight is concentrated at the extremity.

From eq. (9) we see that the shearing force is not constant as in the last case, but varies as x. It is greatest at A.

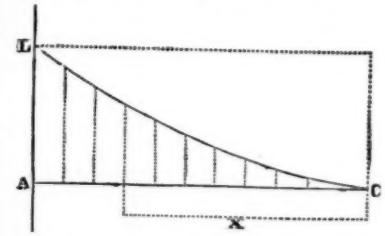

FIG. 12.

Geometrically. The equation $M = \frac{1}{2} w x^2$ corresponds with that of a parabola with vertex at C and axis vertical. Lay off A L (Fig. 12) $= \frac{1}{2} w l^2$, and through L and C draw a parabola. The ordinates of this parabola (dotted in the figure) will represent the moments at the several points.

The equation $T = w x$ is represented by the triangle A P C (Fig. 13), which

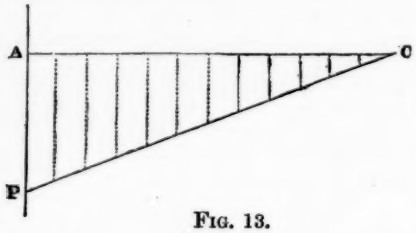

Fig. 13.

therefore gives the shearing stress at every point of the beam when A P is taken $= w l$.

Corollary 1. When the load is distributed over only a part of the beam as in Fig. (14), let R C$=m$=the loaded

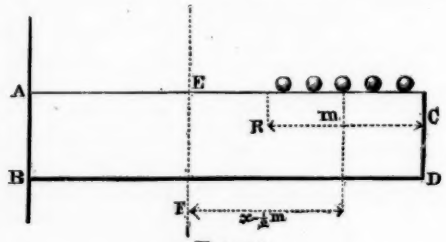

Fig. 14.

part, and take the other letters as before. Then the equations for any section in the loaded part are evidently the same as those just obtained, viz. :

$$\left.\begin{aligned} \tfrac{1}{2} w x^2 = \frac{1}{6} S b d^2 = M \\ \text{At R} \qquad \tfrac{1}{2} w m^2 = M \\ \text{And} \qquad T = w x \end{aligned}\right\} \quad (12)$$

But at any section E F between A and R the moment of the load is $= w m (x - \frac{1}{2} m)$, the latter factor being the distance from the centre of gravity of the load to the section E F. The moment of resistance having the same form as before, we have for the equation of moments for any section in R A

$$w m (x - \tfrac{1}{2} m) = \frac{1}{6} S b d^2 = M \quad (13)$$

At A this becomes

$w m (l - \frac{1}{2} m) = M$, the greatest moment.

The shearing force at E F being equal in amount and opposite in direction to the whole load between E F and C will be

$$T = w m \quad (14)$$

Geometrically. For the moment S: lay off A C $= l$ and C R $= m$ (Fig. 15). At

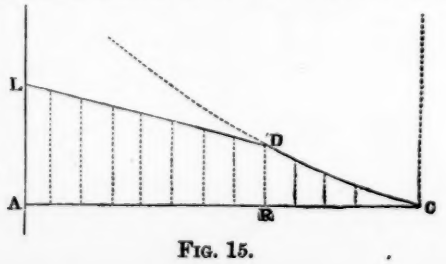

Fig. 15.

R erect $DR=\frac{wm^2}{2}$, and at A make $AL=M_o$. Through C and D draw a parabola as in the last case, and (since eq. [13] is of the first degree) through D and L draw a straight line. Then from C to R the ordinates of the parabola represent the moments, and from R to A they are represented by the ordinates of the trapezoid RL. For the shearing stress (Fig. 16), lay off from R, $RN=wm$.

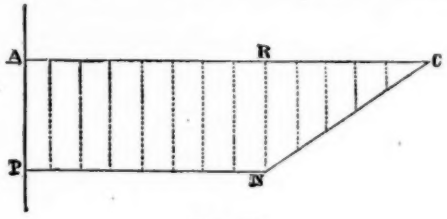

FIG. 16.

Draw CN and NP. Then the triangle CRN (corresponding to the equation $T=wx$) gives the shearing force at each point in CR while the rectangle RP (corresponding to the equation $T=wm$) gives the force in the remaining segment of the beam.

Corollary 2. When there is a load W at the extremity C, in addition to the load uniformly distributed over the beam (Fig. 17), we have a combination of Cases I. and II. and the moment of the external forces at any section, EF, is

$$\tfrac{1}{2}wx^2+Wx$$

Hence the equation of moments is

$$M=\frac{1}{6}Sbd^2=\tfrac{1}{2}wx^2+Wx \qquad (15)$$

This is greatest at A, or

$$M_o=\frac{1}{6}Sbd^2=\tfrac{1}{2}wl^2+Wl \qquad (16)$$

The shearing force

$$T=wx+W \qquad (17)$$

At A

$$T_o=wl+W \qquad (18)$$

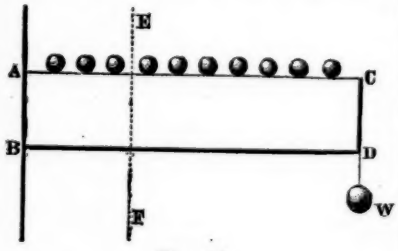

FIG. 17.

Geometrically. The simplest way of representing the moments is to construct those due to each kind of weight, and then combine them. Thus, let $M'=\frac{wx^2}{2}$ and $M''=Wx$. Construct M′ as in *Case II.*, it being represented by a parabola with vertex at C and axis vertical, and M″ as in *Case I.*, it being represented by

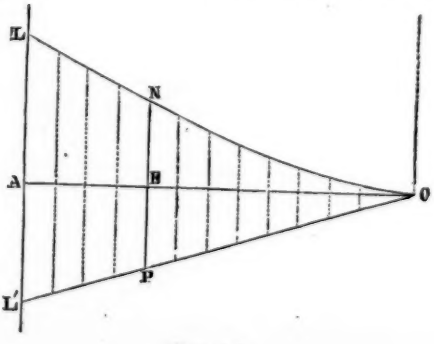

FIG. 18.

a triangle (placed under A C for convenience). Since $M = M' + M''$ from eq. (15) we have the total moment at any point E (Fig. 18) represented by the sum of the ordinates of these two figures=N P Fig. (18.)

The moments may also be represented by the parabola corresponding to eq.

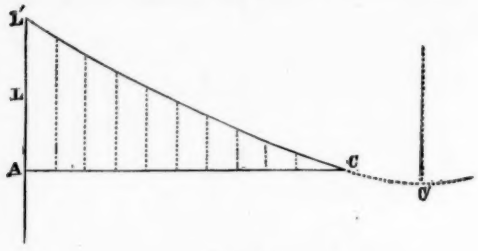

FIG. 19.

(15) as in Fig. (19.) This parabola has its vertex at C′ and not at C. Of course, only that part of the curve between C and A is applicable to our purpose.

The shearing force is represented by adding the triangle N P P′ Fig. (20) representing the variable part wx of T to the rectangle C P which represents the constant part W of T.

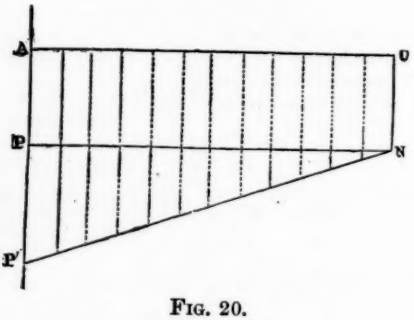

FIG. 20.

EXAMPLE.

Discuss the forces when the load is distributed as shown in Fig. (21) assuming various values for L N and N C as well as for w and W.

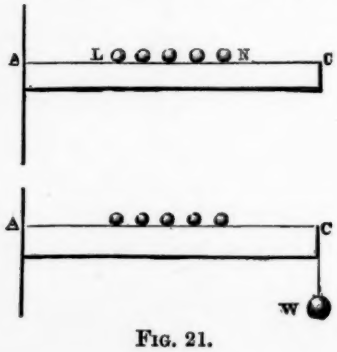

FIG. 21.

Case III.

Let the beam whose length is l rest upon supports at B and D (Fig. 22) and

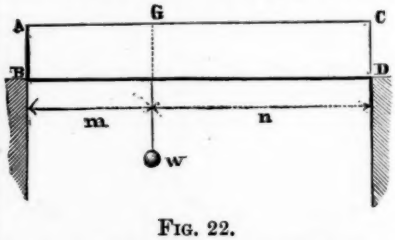

FIG. 22.

let it be loaded at some point G with a single weight W. Let m and n be the

segments into which the beam is divided at the point G of the application of the weight.

First find the proportions of the weight supported at B and D, or in other words, the reactions of the supports. By the principle of the lever the respective portions of the weight supported at B and D are inversely proportional to the distances of these points from G. Thus, let W′=reaction at D and W″=reaction at B and then

$$W' : W'' :: m : n$$
$$W'' + W' : W' :: m+n : m$$

But $W'+W''=W$ and $m+n=l$

$$\therefore W'=\frac{m}{l}W$$
$$\text{And so} \quad W''=\frac{n}{l}W \qquad (19)$$

Now apply the conditions of equilibrium to any part A E of the beam counting from A. Fig. (23).

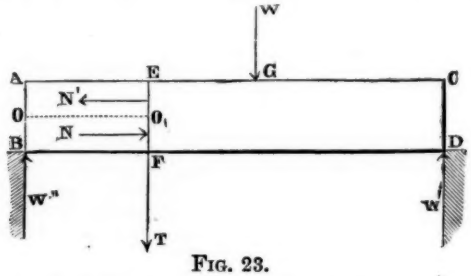

FIG. 23.

1st, Between A and G. $\Sigma X=0$ merely indicates the equality of N and N′, as these are the only horizontal forces. $\Sigma Y=0$ shows that the shearing force at the section E F is downwards

$$\text{and}=W'' \quad \therefore \quad T=W''=\frac{n}{l}W \qquad (20)$$

$\Sigma M=0$. The joint moment of N and N′ is as before $=\frac{1}{6}S\,b\,d^3$. That of T is zero. The only other force acting on A E is W″, the reaction of the abutment. Let $O\,O_1=x$. Then the moment of W″ is

$$W''x=\frac{n}{l}.Wx$$

$$\text{Hence} \quad \frac{n}{l}.Wx-\frac{1}{6}S\,b\,d^3=0$$
$$\therefore \frac{n}{l}Wx=\frac{1}{6}S\,b\,d^3=M \qquad (21)$$

2d, Between G and C (Fig. 24). Here,

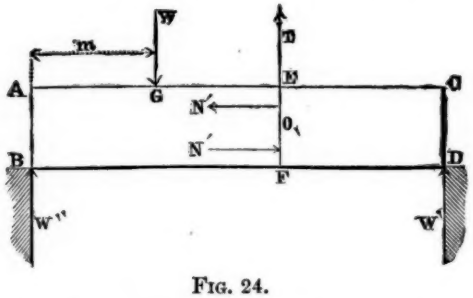

FIG. 24.

between A and E are the two external forces W″ at B and W at G. Hence the shearing force at E F is upwards and

$$T=W''-W=-W'=-\frac{m}{l}W. \qquad (22)$$

For $\Sigma M=0$ we have

$$-\frac{1}{6}S\,b\,d^3+W''x-W(x-m)=0$$
$$\therefore \frac{n}{l}Wx-W(x-m)=\frac{1}{6}S\,bd^3=M \qquad (23)$$

The greatest value of eq. (21) is at G, where it becomes identical with eq. (23) for the same point. This value is

$$\frac{m.\,n}{l}\,W=\frac{1}{6}\,S\,b\,d^2=M_0 \qquad (24)$$

At A and C the moments are zero.

Geometrically. From eq. (21), which is of the first degree, it is seen that the moments vary in A G as they did in *Case I.* Hence they may be represented by the ordinates of the triangle A L G. (Fig. 25).

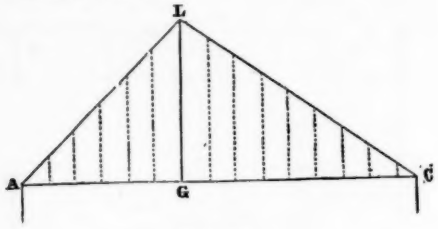

FIG. 25.

Eq. (23) is also that of a straight line cutting the axis of X at C. Hence the moments in G C are represented by the triangle G L C (Fig. 25). The shearing

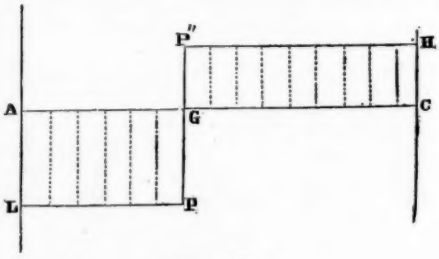

FIG. 26.

force in A G is represented by the rectangle A P and that in G C by the rectangle C P′.

Note, That the maximum moment (at G) corresponds to the point where the shearing force passes through zero.

Corollary 1. When the weight W is at the middle of the beam we have

$$n=m=\tfrac{1}{2}\,l$$
$$W'=W''=\tfrac{1}{2}\,W$$

Then eq. (21) becomes

$$\left.\begin{aligned}\tfrac{1}{2}\,W\,x&=\frac{1}{6}\,S\,b\,d^2=M\\ \text{and (24) is}\qquad\\ \tfrac{1}{2}\,W\,(l-x)&=\frac{1}{6}\,S\,b\,d^2=M\end{aligned}\right\}\ (25)$$

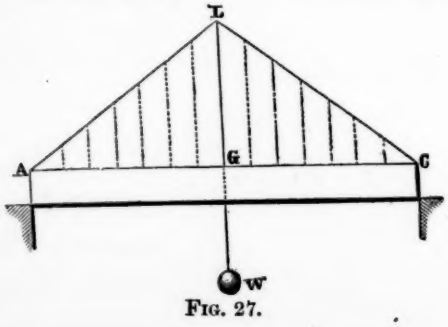

FIG. 27.

At the centre $M_0 = \frac{1}{2} W . \frac{1}{2} l = \frac{1}{4} W l$ (26)

The triangles A L G and G L C (Fig, 27) represent the moments in this case. G L having been laid off $= \frac{1}{4} W l$.

The shearing force throughout the beam is then $T = \frac{1}{2} W$ (27) as is shown in the rectangles (Fig. 28).

Comparing the value of M_0 given in

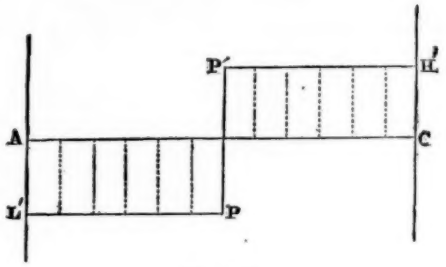

FIG. 28.

eq. (5) *Case I.* with that of M_0 in eq. (26) we see that the load and the length being the same, a beam will bear *four* times as much with both ends supported, and the load placed in the middle as it will do with one end fixed and the other loaded.

Corollary 2. When there are several weights, as in Fig (29), the moment of the external forces at any section is that

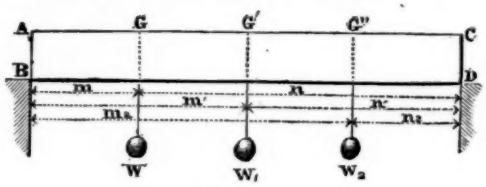

FIG. 29.

due to the action of all the weights. Let the segments into which the weights W, W_1 and W_2 divide the beam be m and n for W, m_1 and n_1 for W_1 and m_2 and n_2 for W_2.

Let R_1 = reaction of abutment at B and
R_2 = reaction of abutment at D and
l = length and let x be counted from A as before.

The reaction of the abutment at B due to these weights is

$$\left.\begin{aligned} R_1 &= \frac{n}{l} W + \frac{n_1}{l} W_1 + \frac{n_2}{l} W_2 \\ \text{So at D } R_2 &= \frac{m}{l} W + \frac{m_1}{l} W_1 + \frac{m_2}{l} W_2 \end{aligned}\right\} (28)$$

For any section between A and G, R_1 is the only external force and hence the equation of moments is

$$R_1 x = \frac{1}{6} S b d^2 = M \qquad (29)$$

The shearing force is $T = R_1$ (30)

For every section between G and G' the weight W is to be taken into consideration and the equations are:

$$R_1 x - W(x-m) = \frac{1}{6} S b d^2 = M \qquad (31)$$

$$T = R_1 - W \qquad (32)$$

For any section between G' and G'') we have: (33)

$$R_1 x - W(x-m) - W_1(x-m_1) = \frac{1}{6} S b d^2 = M$$

$$T = R_1 - W - W_1$$

For any section between G'' and C

$$\left.\begin{aligned} R_1 x - W(x-m) - W_1(x-m_1) - W_2 \\ (x-m_2) = \frac{1}{6} S b d^2 = M \\ T = R_1 - W - W_1 - W_2 \end{aligned}\right\} (34)$$

The location of the greatest moment

is most readily determined by geometrical construction.

Geometrically. The moments are represented in Fig. (30) by constructing separately those due to each weight and then combining them. Thus, the moments produced at every point in the beam by the weight W are represented

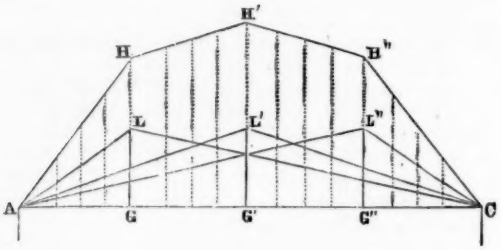

FIG. 30.

by the triangle A L C (Fig. 30), in which G L equals the greatest moment due to $W\frac{n}{l}Wx$. Similarly A L′ C represents those due to W_1, G′ L′ being $=\frac{n_1}{l} W_1 x$, and A L″ C gives those due to W_2, G″ L″ being $=\frac{n_2}{l} W_2 x$.

Now, if at every point we add together the ordinates of these three triangles for that point, and lay them off above A C we shall get a polygon A H H′ H″ C, which represents eqs. (29) (31) (33) and (34) and gives the total moment at any section. The greatest ordinate of this polygon will, of course, show the location of the maximum moment. This will be at G or G′ or G″, according to the relative amounts and positions of the weights W, W_1, and W_2. In the fig. it is at G′. Hence from eq. (31)

$$R_1 m_1 - W(m_1 - m) = \frac{1}{6} S b d^2 = M_0 \quad (35)$$

The shearing force may be represented as in Fig. (31). It is greatest in that

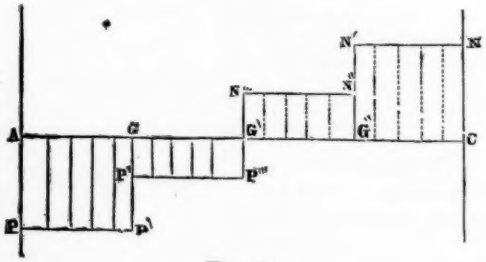

FIG. 31.

one of the two end segments which corresponds to the greater of the two quantities R_1 and R_2.

Note, That in this case the simplest way of finding the point of maximum moment is to construct the figure representing the shearing force, and the point when the shearing force passes through zero (G′ Fig. 31) is the point sought.

EXAMPLES.

1. Let l=20 ft. m=5 ft. m_1=10 ft. m_2=15 ft. W=1 ton W_1=2 tons W_2=3 tons. Find the maximum moment.

2. Find the size of a rectangular wooden beam where

l=15 ft. m=3 ft. m_1=6 ft. m_2=14 ft. W=1 ton $W_1=\frac{1}{2}$ ton W_2=2 tons S=1,000 lbs. and $d=4\,b$.

EXTRACTION OF THE PRECIOUS METALS CONTAINED IN COPPER PYRITES.

Translated from the French of F. CLAUDET,* by ED. DAVID HEARN.

From the "Mining Journal."

SULPHURIC acid, which occupies a prominent position among the chemical products employed in industrial pursuits, was long made almost exclusively from the sulphurs of Sicily; but on the one hand fiscal measures which interfered with their exportation, and on the other the progressive increase in the consumption of sulphuric acid, led the manufacturers to substitute for sulphur the pyrites which is found in almost all countries. It is from Spain and Portugal that the English manufacturers draw the greater part of the pyrites which they use, and as they are more or less cupriferous, the residuum after the extraction of the sulphur was principally sold to the copper smelters, who, owing to oxide of iron constituting the greater part of the residuum, employed it as flux for the smelting of quartzose copper ore; in this operation the copper in the pyrites was recovered, but naturally all the iron was lost in the slag. The extraction of copper from its ores by the wet way, first practiced by Mr. Longmaid, then applied by Mr. W. Henderson to the pyrites of Spain and Portugal, no longer caused this loss of iron; this process has been largely developed, resulting in a constant increase in the importation of pyrites, which now reaches to from 400,000 to 500,000 tons per year, and goes on increasing. The pyrites sells according to its produce for sulphur and for copper; manufacturers who only buy it for te sulphur re-sell the burnt ore to works in which the copper is extracted. It is a work of this kind that I and Mr. J. A. Phillips, both graduates of the School of Mines of Paris, have established at Widnes, near Liverpool. The pyrites of Spain and Portugal is composed (the proportions only varying within very small limits) of the different elements of which the following analysis will give an example; it is that of a sample from the San Domingo Mines from the working of which, ably developed by Mr. J. Mason, about one-half of the pyrites are supplied.

Sulphur	49.00
Arsenic	0.47
Iron	43.55
Copper	3.20
Zinc	0.35
Lead	0.93
Lime	0.10
Water	0.70
Quartzose residue	0.63
Oxygen and Loss	1.07
	100.00

In the last item of 1.07 traces of a large number of metals are found. This pyrites, after having been burnt for the manufacture of sulphuric acid, is the material which is treated for the extraction of the copper; it then contains, with but slight variation:—

Sulphur	3.76	
Arsenic	0.25	peroxide.
Iron	58.25=	83.00
Copper	4.14	
Zinc	0.37	
Cobalt		Traces.
Silver		Traces.
Lead	1.14	
Lime	0.25	
Insoluble residue	1.06	
Water	3.85	
Oxygen and loss	26.93	
	100.00	

As to the silver which is only mentioned as "traces," it is very difficult to assay it precisely in this kind of ore; however, the numerous assays that I have made have enabled me to estimate the quantity between 0.0020 and 0.0028, or from 20 to 28 grammes to the ton. But small though this proportion may be, I did not doubt that we could succeed in extracting it with profit, and this I have done by a process allied to that of the extraction of copper by the wet way, a short description of which I will now give:—We commence by stamping and washing the residue of the pyrites, then they are roasted with chloride of

* "Nouveau Procédé pour l'Extraction des Métaux Précieux contenus dans les Pyrites Cuivreuses." Par F. CLAUDET, Présente á l'Academie des Sciences. Paris, Hennuyer.

sodium in a reverberatory furnace at a very low temperature ; the oxidation of the metallic sulphides and the decomposition of the chloride of sodium which follows give rise to the formation of sulphate of soda and soluble chloride of copper. When we are satisfied by trial of samples that the ore has been properly roasted it is taken out of the furnace, and when it has sufficiently cooled it is thrown in to about three-fourths fill a large wooden tank, with a double bottom forming a filter, and is washed with several waters slightly acidulated with hydrochloric acid until the copper is taken up. There remain in the tank the insoluble portions which consist almost entirely of oxide of iron, and of which the subjoined analysis will give an example :—

Peroxide of iron...	96.20=67.35 metallic iron.
Lead, as sulphate..	0.86
Copper.....	0.18
Cobalt.....	Traces.
Alumina.....	0.45
Lime.....	0.46
Soda.....	0.10
Phosphoric acid.....	No traces.
Arsenic acid.....	Traces.
Sulphuric Acid...	0.49
Sulphur.....	0.16
Chlorine.....	0.03
Silica.....	1.22=100.15.

This oxide of iron in consequence of its uniform composition and fine state of division, is sold to the iron manufacturers, who use it with advantage for fettling the puddling furnaces.

Returning to the mother liquid from which the copper has to be extracted, it is run into other tanks, in which fragments of iron, such as scrap iron, have been placed ; chloride of iron is formed, and the copper is thrown down, taking with it the small quantity of silver of the ore which was dissolved in the liquor. The copper precipitate is then melted and refined to bring it to the state of marketable copper. In the water from which the copper has been separated there are also found salts of iron mixed with alkaline salts which are not acted upon, but by subsequent operations we have been able in our works to obtain, and profitably, too, on the one hand, sulphate of soda in a state of almost absolute purity, and on the other, oxide of iron in so fine a state of division that it is applicable to the polishing of looking-glasses. The waters before the precipitation of the copper by the iron contains, as we mentioned, the silver of the ore dissolved in the state of chloride; to extract it we first naturally think of precipitating it by metallic copper, but silver, being soluble in a mixture of chloride of sodium and deutochloride of copper, the precipitation cannot take place so long as all the deutochloride is not converted by the metallic copper into a protochloride, and then the small quantity of silver is probably found precipitated with the copper in excess, and also with the protochloride of copper which the chloride of sodium is no longer sufficient to dissolve. We must then have recourse to a fresh process of separation, and the expense of this complicated operation absorbs more than the value of the silver ; the process then is not commercial. There is another means of separating the silver from the copper, which consists in making a sulphate of copper of the precipitate ; but the great aim in the treatment of the mineral is the production of metallic copper, and not sulphate of copper, the consumption of which is very limited, so that the process is only applicable within narrow limit.

I had then to seek another mode of separation, and I succeeded, after numerous trials, to discover and put in practice a process which I will now describe; it is founded on the fact that iodide of silver is almost entirely insoluble in a solution of chloride of sodium at the ordinary temperature. The ore roasted with common salt undergoes, as we have said, several washings, yet but little else than the three first waters contain a sufficient quantity of silver to be worth treating. We have ascertained by experiment that the two first waters contain 83 per cent. and the three first waters 95 per cent. of all the silver dissolved. According to the analysis of one of these waters, marking 1.24 of the ærometer, a cubic metre of this liquor contained:

Sulphate of soda....Kilos.	144.171
Chloride of sodium.....	63.914
Chlorine in combination with metals...	66.143
Copper	52.855
Zinc.....	6.857
Lead.....	0.571
Iron.....	0.457
Lime.....	0.743
Silver...	0.0437=335.7547

We have neglected in this analysis the small quantities of arsenic, bismuth, &c. This result is only given by way of example, for the silver which we quote 43.7 grammes varies in our operations from 25 to 27 grammes per cubic metre, according to the richness of the mineral and the degree of concentration of the liquor. It is then the water from the three first washings only that we use. We run them into a wooden tank, where they are left to settle, so that solid matters held in suspension may separate, and, in order not to employ more iodide of potassium than is absolutely necessary, we first assay the silver contained in the liquor. For this purpose we take a fixed measure of it, dilute it with water, adding a little hydrochloric acid, to keep all the copper in solution; then we pour in a few drops of a weak solution of iodide of potassium, which changes the soluble chloride of silver into the insoluble iodide of silver at the same time that by the addition of a solution of acetate of lead we cause the formation of a strong plombiferous precipitate, which contains all the silver. This precipitate is dried, and then melted with a flux to which metallic iron is added; the resulting argentiferous lead is cupelled, and from the weight of the button of silver the quantity contained in the liquor is determined.

The clear titrated liquor is then passed into another tank, and the quantity of iodide of potassium found to be necessary by the assay is added, and it is diluted with a quantity of water equal to about a tenth of that of the cupreous liquor; the whole of the liquor is then shaken and left to settle for 48 hours; the supernatant liquor is then clear; it is drawn off, and the tank is refilled for repeating the operation, and so on.*

Once a fortnight we collect all the deposit which has accumulated; it is principally composed of sulphate of lead, iodide of silver, and salts of copper. These latter are readily separated by washing with weak hydrochloric acid. The deposit, cleansed from the salts of copper, is decomposed with metallic zinc, which in the presence of water rapidly and completely reduces the silver by uniting with the iodine, and forming soluble iodide of zinc. There is thus produced—1. Soluble iodide of zinc, which, separated by filtration, is titrated, and used as a substitute for the iodide of potassium in subsequent operations to precipitate fresh quantities of silver.—2. A deposit rich in silver, composed in a great part of lead in the metallic state, and as a sulphate containing besides various substances, of which the subjoined analysis of a dried sample may be given as an example:

Silver	5.95
Gold	0.06
Lead	62.28
Copper	0.60
Oxide of zinc	15.46
Oxide of iron	1.50
Lime	1.10
Sulphuric acid	7.68
Insoluble residue	1.75
Oxygen, and loss	3.62=100.00

This analysis shows that all the iodine of the iodide of silver has entered into combination with the zinc, and re-become soluble, since the deposit contains none or only traces. Gold, which has not before been mentioned, appears here for the first time, and we may ask how this happens? It exists then in the ore, and it would appear that in the operation of roasting it forms chloride of gold, which, rendered more stable by the presence of chloride of sodium, is not reduced at the low temperature of the roasting; it then enters into solution with the silver, and, like it, it is precipitated by the iodine. It is now easy to separate from this product the precious metals by the ordinary processes employed by smelters who treat gold and silver matters. It will, no doubt, be interesting to know the results we have obtained by the application of the process during a year. The process was applied in 1871 (the paper was read in 1872) to 16,300 tons of burnt pyrites, from which we extracted of silver 333.242 kilos., and of gold 3.172 kilos., representing a little more than 20 grammes of the precious metal per ton, and producing £3,232 after deducting the cost of melting and refining. The expenditure directly connected with the precious metals amounted to £416, which includes the cost of 137 kilos. of iodine, representing the loss of that material,

* These liquors, which are drawn off, still contain a small proportion of silver in solution, about 5 grammes per cubic metre, for, as we have mentioned, the iodide of silver is not absolutely insoluble in these liquors. It is scarcely necessary to add that they re-enter again in the ordinary working for the extraction of the copper.

and 1,900 kilos. of zinc, and it is remarkable that the gold which exists in the ore in appreciable quantity suffices to cover the whole cost of the process. The cost of the iodine, already large, has become much more considerable through the abnormal increase in the price of the product, and has called my attention to the direct employment that might be made of the lye from the ashes of seaweeds instead of iodide of potassium. The recent experiments we have made in this direction have answered my expectations, and not only have we succeeded in utilizing by this means all the iodine contained in the seaweed, and great part of which is, as we know, at present lost, but the trials have suggested to me the idea of an inverse operation, to which I am now giving attention, for making iodine, and which consists in precipitating this metalloid from the seaweed lye by means of a salt of silver. This extraction of 20 grammes of precious metal from the ton of burnt pyrites is, I admit, not very considerable; but when we consider that the process could be applied to 350,000 tons of ore, and thus produce, with a good profit, too, 7,200 kilos. of the precious metals, of the value of £68,000, it will be seen that it is an annual result not to be neglected.

This process can also be employed for various other copper ores susceptible of treatment by the wet way, and we have begun to apply it to the copper ores of Cornwall, which generally contain more silver than the Spanish pyrites, and which hitherto have been worked by the dry way, and solely for the extraction of the copper. The results which we have just recorded show how highly important it is, in metallurgical operations, to deal with large masses; we thus obtain profits where the same process applied to limited quantities could only result in loss. We will make the further remark upon this subject that large quantities of the precious metals have been lost, and are still lost daily, in metallurgic operations, and we do not doubt that many of the residues in various parts of the globe which have been neglected as too poor will one day be re-treated to separate the gold and silver which they contain.

THE DRAINAGE OF CALCUTTA.

From "The Builder."

Ten years ago Sir John Strachey declared that the capital of British India was "a scandal and a disgrace to a civilized Government," and asserted that it was literally unfit for the habitation of civilized men. He declared that the most important streets and thoroughfares of the northern division of the city formed to all intents and purposes a series of huge public latrines, the abomination of which could not be adequately described. And he vehemently added, the other cities and towns of India were almost faultless when compared with the metropolis. Yet at that time sanitary questions were altogether unknown in India, and Miss Nightingale had reported that no one of the presidential cities of India had arrived at that degree of civilization in their sanitary arrangements which the worst parts of our worst towns had reached before healthy reform in such matters sprang up in England at all. This reproach has now been wiped away from the Indian capital, and there are signs that Bombay and Madras will soon be rendered salubrious. At Norwich, in November last, Miss Nightingale was able to state that "the drainage of Calcutta bids fair to be a wonder of the world, and said that the city had become more healthful than Manchester or Liverpool, and might even be considered a *sanitarium* compared with Vienna or Berlin." How has the change been accomplished?

Calcutta lies in close proximity to a vast stagnant marsh, known as the Salt Water Lake. Even in its infancy the settlement was unhealthy, and as it grew in size its insalubrity increased. Cholera continually haunted it, fevers and dysentery made it their home, and when it had come to be termed the City of Palaces, it was equally well known as the City of Pestilence. But the traders

who frequented its bazaars risked their health for the sake of the rupees which flowed into their coffers; the servants and officers of John Company had too many wars on hand, and too many States to annex, to pay much heed to the healthiness of the town, and to the soldiery the chances of death on the field or under the friendly guns of Fort William were about the same. But at length the mortality of Calcutta became so notorious that the Government could no longer overlook it, and a committee was appointed to inquire into the causes of the prevalence of perennial fever, and to propose remedial measures. This committee sat for several years previously to 1840, amassed a great amount of repulsive evidence, and in the end proposed the establishment of a fever hospital. The Medical College Hospital was accordingly founded; but while it afforded relief to the afflicted, and did save a few lives, such a solitary institution could not materially diminish the death-rate. At that time, and for many years afterwards, the affairs of the city were managed by a Conservancy Board, composed of two European and two native commissioners; but although these gentlemen were anxious to do their duty, they lacked professional skill to direct their efforts, and wasted their energies in futile projects. The night soil was collected from house to house by scavengers, and conveyed in open carts to the river, into which it was thrown at a point above the harbor. The stable refuse and house rubbish were shot into the streets and road-ways, and subsequently carted away to fill up disused tanks and ponds, and to raise the foreshore of the river; while the surface water of the thoroughfares and compounds, the slops from the houses, including urine, and the storm water were allowed to find their way by surface gutters into the Hooghly and into the Circular Canal—a deep cutting which almost surrounds Calcutta to the eastward. The whole subsoil of the city was saturated with filth which had spread from innumerable cesspools, and with water which had percolated through from the Hooghly, or had fallen during the monsoons. Only vile drinking-water was needed to render the Indian capital the permanent abode of plague and pestilence—and this was also provided; for wells and the river alike were impregnated with sewage matter. In the tropics with so much of the results of decomposition in air, earth, and water, it is surprising that life was at all endurable, and that the people submitted to the nuisance so long. But although the European inhabitants grumbled, the native Commissioners opposed all schemes for extensive reform; and affairs rolled on on the filthy old groove until, in 1855, Sir Frederick Halliday was appointed to the new office of Lieutenant-Governor of Bengal. An administrator so able at once detected the foul spot, and succeeded in convincing the Commissioners that they were personally incapable of superintending the work of reform. By his advice a professional adviser was called in, and Mr. William Clark, C. E., was appointed to the post. In the following year that gentleman submitted a scheme, with estimates attached, for the drainage of the city, and a committee was appointed to report upon it. After deliberations extending over eighteen months, the committee reported favorably upon the project, and it was sent on with their endorsement to the Government. To make assurance doubly sure, the plans, about which little difference of opinion then existed, were handed over for supervision to Mr. Rendel, C. E., who happened to be in India at the time. By him they were carried to England; but after considering them for ten months he reported unfavorably with regard to them, and proposed a counter scheme of his own. Then the mutiny broke out; people had other work to do; and the whole affair was shelved for a time. However, when the rebellion had been suppressed the Government at an early date returned to its previous intentions, the rival projects were compared; the proposals of Mr. Clark were preferred, and orders were given to begin the work. It was in 1859 that the undertaking was commenced, and it is not quite complete now.

Mr. Clark's scheme comprised outfall works and large brick sewers in every part of the town, which lay within 1,000 feet of the main drainage lines, leaving minor pipe sewers for future consideration. The large sewers, five in number, and varying from 6 feet to 8 feet in

height, extended from the river to the east at right angles across the town; and these sewers were connected at their eastern extremity by an 8½ feet sewer placed beneath what is known as the Circular Road. From the middle of this road the outfall branched off in a due easterly direction in the bed of what was formerly the Entally Canal, which, being useless, was filled up for the purpose. The outfall sewer, 16 feet high, was continued to a length of 3,284 feet, to a channel cut in the marsh or salt water lake before referred to, and thence it is eventually to be conducted to a distance of ten miles from the city, and there discharged into the tidal stream of Sunderbund. From the river, eastward, the level of the surface of the land falls at the rate of 3 feet per mile, and eventually forms the Salt Water Lake. The waters of the Hooghly can thus be utilized at discretion, in flushing the sewers during the dry season; while, at other times, the storm water can be discharged into the river at low tide.

The perfection of the drainage scheme necessarily involved one for water supply. Accordingly, Mr. Clark proposed to take water from the Hooghly, seventeen miles above Calcutta, pump it into large settling reservoirs, filter it, and pass it down to the city in iron mains, 42 inches in diameter. Thence it was meant to pump it during the night into a large reservoir in the centre of the town, from which it could be pumped for distribution during the following day. This project was sanctioned in 1865; the works were commenced at the end of 1866, and were completed in three years. The daily delivery is about eight million gallons for a population of about 500,000 inhabitants. It is distributed under a pressure of 50 feet by engines fixed near the central reservoir. Stand-posts are fixed in the streets for supplying the poorer classes, while house-pipes may be connected with the mains if it be so desired. The cost of these works was about £600,000, which was advanced by the Government to the Municipality at 4½ per cent. After having served domestic purposes the eight million gallons of water are discharged into the sewers by the drains; this water flows by gravitation, with the subsoil water and the light shower water, to the pumping-station, where it is disposed of as described. The sewers are divided into three classes. First, the large ones branching off from the river to the Circular Road, and ultimately to the pumping-station. There are ten miles and three-quarters of this sort. The second-class are also brick sewers from 3 feet to 5 feet high, and are laid along the principal streets at right angles to those of the first-class. These sewers are twenty-three miles long, and both these and those of the first-class are finished. The third-class, which will drain the narrow lanes and the interior of the blocks of buildings surrounded by the first and second-class, will consist of stoneware piping. They also are very nearly complete, and their total length is estimated at seventy-nine miles. Thus, when the whole network is finished there will be 113 miles of sewers, which represent the road mileage of the city.

Considerable difficulties attended the execution of the scheme, and there were some differences of opinion as to the mode of carrying it out, but they were overcome, one after another. Native bricks were employed; a large brick-making establishment was set on foot at a place nine miles above Calcutta, and the native brickmakers soon succeeded in producing, with their simple apparatus, bricks as good as, and less expensive than, those turned out by the European machines which had been imported. For many years the brickfield had produced about 8,000,000 of hand-made bricks. As brick-dust, or what is known locally as "soorkie," is employed instead of sand with lime in making mortar, about 500 maunds of it were supplied every day. Stoneware pipes, varying from 6 inches to 12 inches in diameter, were supplied from Doulton's potteries at Lambeth; and when laid down the lowermost half of the openings was united by cement, and the upper half by puddled clay, through which the subsoil water was permitted to percolate. The saturated subsoil was a great obstruction to progress. A trench, dry overnight, would be found to be more than half full of water in the morning; and no amount of pumping was equal to the task of keeping the trenches dry enough. After many abortive attempts, Mr. Clark adopted the plan that has been fol-

lowed in London of laying a stoneware pipe at the bottom of the trench, and covering it with a bed of concrete, upon which the brick sewer was built. The lowermost part of the inner circumference of the sewer was coated with Portland cement, and made water tight, but the other half was unprotected. The walls varied according to the size of the sewers from 5 inches to 20 inches of brick-work in rings. The subsoil water enters the sewers either at the bottom, by means either of the small stoneware pipe or by percolation through the upper half of the brickwork; and the plan has been so successful that its level has been reduced by 7 feet or 8 feet. The sewers are employed to remove the subsoil water, the drainage of the houses, and the rain water. In a tropical country, the rainfall is a most important consideration, that of Calcutta varying from 75 inches to 90 inches per annum. Hence the sewers had to be made of exceptionally large size, and it is said they can take the equivalent of a quarter of an inch of rain per hour, which, if collected, would be represented by a running-stream 40 feet wide, 8 feet deep, and flowing at a velocity of 4 feet per second.

During the monsoons, when the storm-water falls in sufficient quantities to over-power the pumps at the pumping-stations, it is discharged by special outlets into the Circular Canal, adjoining the Circular Road, whence it flows off into the natural streams of the country eastward. It is admitted into the sewers by gully-gratings placed at the sides of the footpaths, which gratings cover a deep pit provided to intercept the road grit, which is removed by manual labor. Such of the grit as finds its way along the sewers to the pumping-stations is intercepted there. The stable-litter, kitchen-stuff, and other more solid refuse of the town are removed from every house by municipal carts daily to a railway that runs along the Circular Road, carried by it to the Salt Water Lake, and there deposited. There have been various proposals for utilizing the sewage-matter and litter at the place of their deposit, but no action has yet been taken, atlthough it is very unlikely that such a profitable deposit will remain long without being turned to good account.

The Calcutta justices are empowered to compel householders to connect their premises by suitable drains with the public sewers, but they are reluctant to enforce their authority, and prefer leaving every man to his own discretion. It is very questionable whether their laxity is to be commended, for much of their outlay is thereby rendered unproductive, and the health of the whole city suffers. The city death-rate, however, has been reduced by more than one half. When the public sewers are not used the householders allow the drainage of their dwellings to gravitate into cesspools and ditches, and it is only when they have become an intolerable nuisance and a source of pestiferous exhalation which cannot be endured that they are cleaned out, and the contents, in a state of active decomposition, are carted away and shot into the sewers. It is gratifying, however, to state that the natives are beginning of their own accord to appreciate the advantages of the public sewers, and to understand the dangers attendant upon the accumulations of filth, within and about their dwellings. Hitherto the cost of connections and other private drainage works has acted as a deterrent to the smaller owners and holders. Recently, however, a shrewd native justice suggested that the English system should be adopted, by which such persons can have their premises drained by the municipal authorities, and pay off the combined interest and cost at a fixed annual rate. The project has been adopted, and it is anticipated will become popular.

The total cost of the drainage works of Calcutta, when completed, will be about £800,000, of which nearly £600,000 have already been expended. The money has been raised partly by municipal debentures bearing 6 per cent. interest, and latterly by a Government loan. The benefits, however, amply compensate for all the expenditure.

NEW SIGNALING APPARATUS.—Mr. W. Leach, of Wigan, has patented an invention which relates to the construction of a signal apparatus for collieries, mines, and other underground works, the object being to combine visible and audible signals from the persons at the bottom of the shaft to the engineer at the pit mouth, such signals remaining visible until the engine has commenced to wind up, and then returning automatically to zero.

REPORTS OF ENGINEERING SOCIETIES.

KING'S COLLEGE ENGINEERING SOCIETY.—At a meeting of this society, held on June 11th, Mr. E. L. Hesketh, A.K.C., read a paper on some experiments in centrifugal pumps, made at the works of Messrs. Easton and Anderson, of Eirth. The author commenced by describing the pumps which were experimented with. The first was a 10 in. pump with trunk engine attached, and the second was a vertical spindle pump with 2ft 6in. fan. He described the way in which the experiments were conducted, and also the method of finding the throw. The best results were obtained when the case was made of a spiral form inside by the temporary introduction of a curved piece of wood. A pump is now being constructed which will have the case cast in a spiral form. In the other pump two other forms of fan were used, viz., Rankine's and the involute. The latter gave by far the best results, but still not satisfactory, as the water rotated inside the pump at such a rate, but the notion was conceived of having curved blades placed in such a position as to utilise the rotary motion of the water and convert it into a vertical one. The paper was illustrated by several diagrams, photographs, and models.

IRON AND STEEL NOTES.

BRIGHTENING IRON.—A Bavarian serial contains a method of brightening iron recommended by Boden. The articles to be brightened are, when taken from the forge or the rolls, in the case of such articles as plates, wire, &c., placed in dilute sulphuric acid (1 to 20), where they remain for about an hour. This has the effect of cleansing the articles, which are then washed clean with water and dried with sawdust. They are then dipped for a second or so in nitrous acid, washed carefully, dried in sawdust, and rubbed clean. It is said that iron goods thus treated acquire a bright surface, having a white glance, without undergoing any of the usual polishing operations. This is a process that those interested can easily test for themselves, but care should be taken with the nitrous acid not to inhale any of its fumes. Boden states that the action of the sulphuric acid is increased by the addition of a little carbolic acid, but it is difficult to see what effect this can have, and it may very well be dispensed with.—*English Mechanic.*

THE DANKS FURNACE IN AMERICA.—Information of a later date than Mr. I. L. Bell's visit to the United States has been received in Staffordshire relative to the working of the Danks furnace in the States. The ex-president of the Iron and Steel Institute in his "Notes of a Visit to Coal and Iron Mines and Ironworks in the United States," said that two establishments at which the Dank system was still in use were the Railroad Mill at Cincinnati, under the personal superintendence of Mr. Danks, and the Mill of Messrs. Graff, Bennett & Co., of Pittsburgh. Mr. Bennett and his Manager—Mr. Williams—Mr. Bell declared to be equally sanguine with Mr. Danks as to the ultimate success of the system. The later information is that Messrs. Graff, Bennett & Co. are increasing their number of furnaces, that they are taking the bloom direct to the Universal Rolling Mill—which has reverse motion—and that upon coming out of the rolls the hot iron is slit to varied widths by powerful cutters. When the Danks process was discussed by the Staffordshire mill and forge managers, on the occasion of their visit to the Ravensdale Works in North Staffordshire, certain of them expressed doubt as to the practicability of dealing with such large blooms as were produced by the rotary furnace, so as to make from them the smaller sizes of finished iron for which South Staffordshire is best known; and it was pointed out that the difficulty might be met by slitting the blooms immediately they left the forge rolls. It would seem as though Messrs. Graff, Bennett & Co. are leading the way in an adaptation of the Danks process to the making of the smaller sizes. If they are successful in this work, what they are doing is of considerable importance to South Staffordshire. Though nothing is known of any present attempt to lay down the Danks plant in South Staffordshire, yet there is a rumor that, at least in one instance, there is a disposition to test the Crampton furnace. Nevertheless, the probability that one or the other, or it may be both, will be forced upon the district at no distant day is pretty generally conceded.—*Engineer.*

PRODUCTION OF PIG IRON IN THE UNITED STATES IN 1874.—The American Iron and Steel Association has received from the producers and from its correspondents full statistics of the production of pig iron in the United States in 1874. The total production was 2,689,413 net tons, against 2,868,278 net tons in 1873, and 2,854,558 net tons in 1872, showing a decrease of 178,865 tons as compared with 1873, and 165,145 tons as compared with 1872. Notwithstanding this decrease, the production in 1874 was much larger than was generally anticipated—much larger even than partial returns made to the Association at the close of 1874 indicated. This unexpected result is, however, susceptible of a satisfactory explanation. As preliminary to this explanation we give the following statistical resume:

Years.	No. of furnaces Jan. 1st.	No. of furnaces built during the year.	Total number of furnaces Dec. 31st.	Out of blast Dec. 31st.	In blast Dec. 31st.	Production of pig iron in net tons.
1872..	574*	41	615	115¶	500	2,854,558
1873..	615	50	665	252	413	2,868,278
1874..	665†	38	701	336	365	2,689,413

* Including 3 spiegeleisen furnaces in New Jersey.

† Two furnaces were abandoned in 1874.

¶ Estimated.

On the 1st of February, 1874, of 701 completed furnace stacks in the country, there were in blast 303 stacks and out of blast 398 stacks. Sixty-two furnaces were blown out in January. These figures indicate the lowest degree of depression reached since the panic up to that date. Since February 1st the number of furnaces *out of blast* has been slightly increased.

The number of new furnaces completed in 1874 was 38, against 50 in 1873 and 41 in 1872. The astonishing number of 46 stacks is reported to us as being in course of erection in 1875, while other new furnaces are projected.

The following States made more iron in 1874 than in 1873: Maine, Vermont, Massachusetts, New York, Virginia, Georgia, Alabama, Texas, West Virginia, Tennessee, Ohio, and Michigan. The following States made less iron in 1874 than in 1873: Connecticut, New Jersey, Pennsylvania, Maryland, North Carolina, Kentucky, Indiana, Illinois, Wisconsin, and Missouri. The district showing the greatest increase during 1874 was the Miscellaneous bituminous coal and coke district in Ohio. The district showing the greatest decrease during 1874 was the Lehigh anthracite district in Pennsylvania.

Utah Territory made her first pig iron in 1874—200 tons of charcoal. After a long rest Oregon, with one furnace, made 2,500 tons of charcoal iron in 1874. Texas made 1,012 tons of charcoal iron in 1874. South Carolina, with eight furnaces, and Minnesota, with one furnace, made no iron in that year.

The production of charcoal pig iron in 1874 was within 1,903 net tons as large as that of 1873, being 572,817 net tons in 1874 against 574,720 tons in 1873.

The total imports of pig iron into the United States in 1874 were 61,165 net tons, against 154,708 net tons in 1873, 295,967 net tons in 1872, and 245,535 net tons in 1871.

The total exports of pig iron from the United States to all countries in 1874 were 16,039 net tons, against 10,104 net tons in 1873, and 1,477 net tons in 1872.—*Abstract from the Bulletin.*

RAILWAY NOTES.

Enormous Engines.—An engine has recently been placed on the Pennsylvania Railroad which weighs seven tons heavier than the ponderous Modoc, whose drawing capacity is almost twice that of an ordinary locomotive. The Modoc is capable of taking eighty loaded cars from Harrisburg to Columbia, while other engines are put to a severe test when they pull fifty cars on that portion of the road. The new locomotive when fully initiated is expected to get away with a hundred cars. The only argument that can be used against large engines is that they are hard on tracks, but as the Pennsylvania Railroad Company has adopted steel rails—able to withstand a far greater pressure than iron rails—the wear will not be material. The introduction of these mammoth engines is considered a very economical measure by the railroad company.—*Iron World.*

The total length of railways thrown open to traffic in Russia during 1874, may be taken as 1160 English miles. The total railway mileage of Russia, including Finland, represented 11,576 English miles on the 1st of January, 1875, which length very nearly coincided with the French railway mileage on the 1st of January, 1874, France showing then a total corresponding mileage of 18,565 kilometres, or 11,510 English miles. At the present time Russia is engaged upon the fourth section of the Losowaja-Seevastopol railway, the Rostow-Wladikawkas line, the Kornescty-Pruhtbridge line, the Fastow-Snamenka line, the Orenburg Railway, the Ural line, and the Vistula Railway.

Three years' experience on the Denver and Rio Grande 3ft. 6in. road has determined the fact that much wider cars can be run with safety than was at first supposed possible on so narrow a gauge. They are now building passenger and freight cars 8ft. wide. The superintendent, Mr. W. Borst, says that, were he to begin anew, he would make all the passenger cars 8ft. 3in. wide, outside measurement, giving room, with a narrow isle, for good double seats on each side, as in wide gauge cars. By placing the sills of the narrow-gauge car so much nearer the rail, an angle of safety is secured amply sufficient to prevent overturning, even at high speed; this also greatly diminishes the oscillation of the car, an important point for the comfort of passengers. A Denver editor gives it as his experience that he can write on a narrow-gauge with less difficulty than on any wide-gauge car, not even excepting the Pullman palace.—*Engineering.*

Incrustation in Locomotives.—Mr. F. Kupka, an engineer at Vienna, writes to the German *Organ for Railroad Progress* of some experiments made by Mr. A. Feldbacher, engineer of the Austrian State Railroad Company, on lining locomotive boilers with sheet copper to prevent accumulations of incrustation. Of the three plates forming the bottom of a locomotive boiler, the two at the ends were covered with sheet copper one millimetre (1.25in.) thick, the middle one being left bare. This engine was run two years, making about 14,000 miles in switching service in the Vienna yard, where the water is the worst on the line. On removing the boiler tubes, a layer of incrustation was found 10 millimetres thick on the iron surfaces and two to three millimetres on the copper; the iron exhibited corrosions 1½ millimetre deep; the copper maintained a perfectly smooth surface, while the iron under the copper had the appearance of new plate. The structure of the incrustation was coarser grained on the iron than on the copper. The cost per boiler is given as 50 dols. to 150 dols. Mr. Kupka summarises the advantages of this practice as follows:—(1) The life of the boiler is increased two or three times, and extraordinary security against explosions is obtained. (2) There is considerably less incrustation on the smooth surface of the Copper, than on the porous and somewhat oxidised iron and steel, and therefore a better generation of steam and utilisation of fuel. (3) The boiler plates may

be thinner without danger, in consequence of the favorable action of the copper in preventing corrosion, and consequently the weight of the boiler may be less. (4) The joints of the plates are made perfectly tight by doubling the thin copper sheets over the iron plates and riveting them in. (5) There is a considerable saving in boiler repairs.—*Engineering.*

RAILWAY ACCIDENTS IN GREAT BRITAIN.—The Pall Mall Gazette says: The returns relating to railway accidents for the last year has just been issued. From these returns it seems that the total number of persons reported as killed to the Board of Trade in 1875 for the United Kingdom was 2425, and injured, 5050. Of the killed, England contributed 1175; Scotland, 211; and Ireland, 39. Of the injured, the numbers for England are 4468; Scotland, 496; and Ireland, 86. It further appears that there were last year in the United Kingdom, to account for all this killing and wounding, fifty-five collisions between passenger trains or parts of passenger trains; 183 collisions between passenger trains and goods or mineral trains, engines, and vehicles standing foul of the line; 75 collisions between goods trains or parts of goods trains; six collisions between two engines, ninety-seven accidents from passenger trains or parts of passenger trains leaving the rails; seventy-four from goods trains or parts of goods trains, engines, &c., performing the same feat; forty from trains or engines traveling in the wrong direction through points; twenty-one from trains running into stations or sidings at too high a speed; 195 from trains running over cattle or other obstructions on the line; fifty two from trains running through gates at level crossing; six from the bursting of boilers, &c., of engines; eight from the failure of machinery, springs, &c., of engines; from failure of tires, 55; ditto of wheels, 13; of axles, 229; of brake apparatus, 1; of couplings, 23; of ropes used in working inclines, 3; of tunnels, bridges, &c., 4; 493 are charged to broken rails; 10 to blocking of portions of permanent way; 8 to slips in cutting of embankments; 28 to fire in trains; 12 to fire at stations or involving injury to bridges or viaducts; 11 are returned as other accidents. Directors hanged for manslaughter, 0.

ENGINEERING STRUCTURES.

IRON ARCHED BRIDGES.—At the last Sessional meeting of the Edinburgh and Leith Engineers' Society, the President, Professor Fleeming Jenkin, read a paper on metal arches. He began by explaining the stresses which occurred in the common masonry arch, illustrating the subject by means of a wooden model of novel description, having each voussoir curved so as to render the arch flexible. It was explained that in papers by Professor Clerk Maxwell, Mr. Bell, and Professor Fuller, of Belfast, methods were given by which the maximum intensity of stress on each part of a metal rib could now be determined with as great accuracy as the stress on the ordinary girders; and Professor Jenkin expressed a strong opinion that the great bridges of the future would be metal arches, which for great spans were essentially more economical than beams, while they also were more beautiful. In illustration, the Bridge of St. Louis, at Cincinnati, was referred to, with a central arch of 520 feet in span. There was no reason why arches of 700 or 800 feet span should not be erected, and in some situations even these great spans would be economical in comparison with a number of smaller openings involving expensive foundations.

THE IMPROVEMENT OF THE TIBER.—The surveys of the deviation of the Tiber, as proposed by General Garibaldi, have just been completed by the Government engineers, and show clearly the great difficulties in a financial point of view which would have to be encountered in carrying out such a project, whether on the right bank or on the left. The deviation on the left bank—which would be the most favorable—would not cost less than 135 millions of francs, or £5,400,000; whilst that on the right, which would entail a certain length of cutting from seventy to eighty metres in depth, is estimated at 200 millions of francs, or eight millions sterling. In our opinion the most feasible scheme so far is that presented some time ago by a well-known engineer, Signor Anderloni, who proposed rectifying the river in its course through the city, giving it a clear waterway of 100 metres, and removing all obstacles—such as the Ponte San'Angelo—which in heavy floods dam back the waters, and cause them to overflow the banks and inundate the city. In the flood of 1870 the water stood at 1.50 above the soffit of the arches of that bridge. Such a work, including a handsome boulevard on each side of the river, with earth embankments for a considerable distance above and below the city, would not probably cost more than fifty millions of francs, or two millions sterling, and would, no doubt, effectually prevent the recurrence of such floods as that of 1870, when, according to Signor Possenti, the President of the Commission for the Tiber, the discharge at Rome reached 2800 cubic metres per second. The removal of the obstacles and the rectification of the river would produce a lowering of the levels of the water in such a flood as that of 1870 of 3.22 metres at Ponte Molle, about 4 kilos. above Rome; of 4.02 metres at Ripetta, where the river enters the city; 1.78 metres at Ripa Grande, where it leaves Rome; and 1.18 metres at the railway bridge, about 1½ kilos. lower still, or 6 kilos. below Ripetta. In this manner the flood level would be reduced at the Ripetta from 17.29 metres above the sea to 13.26 metres, or within the limits of safety. It would be necessary to construct intercepting sewers along the embankment to carry the drainage of the town some distance down the river, and in this manner there would be no danger of those parts of the city which are only 12 metres above the sea being flooded.

PUBLIC WORKS IN JAMAICA.—From an official document just issued with regard to this subject we glean some information of interest to our readers. One of the most important

works being carried out in Jamaica is the construction of new waterworks for the improvement of the water supply of Kingston. In the carrying out of these works, a dam across the Hope River has been constructed for the purpose of increasing the quantity of water flowing into the culvert. Two reservoirs, at the termination of the culvert near the city, are in course of construction. They will contain 5,000,000 gallons of water. Two filter beds have also been constructed. From the reservoirs the water will flow into the city and its suburbs by a system of iron pipes. The main pipe is 21 inches in diameter. The main and supply pipes have been laid down. Already the works have cost more than $50,000, while it is thought that about $5,000 more will be required for their completion. It has also been decided to build new gasworks for the city of Kingston, and a design was submitted by a London gas engineer, but it was considered too costly. Accordingly it was determined to get a plan of a less expensive character. Another important work in Jamaica is the carrying out of the Rio Cobre irrigation scheme. In reference to this Sir J. P. Grant expressed the hope that it would have been finished long ere now, but he has been disappointed, that is to say, with regard to the head works of the Rio Cobre Canal, the trunk line, and the Caymanas branch. With reference to the progress of the works so far it appears that the foundations of the annicut or dam across the river, the most difficult and expensive portion of the work has been completed, and the dam carried to a height of 10 feet above the foundation in all parts, and in some parts much higher. When finished this structure will be in length 320 feet, reaching all across the river when dammed up; in height it will be 48 feet above the bed of the river, and in breadth or thickness it will be 26 feet at the base and 13 feet at the top. It will contain about 238,000 cubic feet of masonry, besides a mass of concrete. The dam will have suitable sluices and a water cushion. Work on the Trunk Canal and the Caymanas branch has made fair progress. The masonry work on the line consist of three calingulates, or waste water wiers, two aqueducts, one culvert, twenty-three bridges, and eighteen falls.—*Engineer.*

A Notable Railway Bridge.—The railway system of India has necessitated some remarkable engineering works, amongst which may be mentioned the Bhore Ghat incline, from Bombay to Central India. This work, 15¾ miles in length, cost, with tunneling, bridges, and embankments, as much as £68,000 per mile, nearly the same as the Semmering Pass in the Noric Alps, joining Vienna and Trieste. The height surmounted in the Ghat incline is 1,831 feet, by gradients averaging 1 in 48, but with 8 miles of 1 in 40, and 1¼ miles of 1 in 37. There are also very numerous railway bridges on the Indian lines, as may be inferred from the fact that one English firm alone, Messrs. Westwood & Baillie, of London-yard, Poplar, have already built more than 16,000 iron bridges for the Bombay, Baroda, and Central India and other Indian railways. The firm referred to have just completed and dispatched the last section of the longest bridge they have ever constructed, probably the longest bridge, when its erection has been completed, then in existence. It is to cross the river Chenab in the Punjaub, and will form a part of the through route from Calcutta and Bombay to Lahore, Peshawar, and Cabool. The Chenab is a tributary of the Indus, and has wide low-lying banks, liable to inundation, that are spanned by the bridge. The substructure is to consist of piers of masonry 10 feet 9 inches thick. The superstructure is entirely of iron, and on the Warren girder principle. The total length between the abutments at each end is 9,088 feet, or 1¾ miles less 51 yards. The whole work has been built in Messrs. Westwood & Baillie's yard, and has been sent out in sections, every separate part marked, so as to fit into its own place. The last section, of about 100 yards in length, that we saw in the yard was an excellent example of exact work, each end responding perfectly to the test of a wire under high strain applied to it. The bridge will have sixty-four spans, of a clear width of 131 feet 3 inches each. It will carry a single line of the metric gauge, that prevails in India, of 3 feet 3 inches. The width over all is 18 feet, 2 inches, which leaves a sufficiently wide clear space for a footway on each side. The main girders, which are 15 feet 9 inches between centres, are 10 feet 4 inches deep, with flanges of 2 feet 6 inches. The cross box girders, of which there are 1,792 in the structure, are placed at 5 feet 3⅝ inches apart. The rivets used in the work have been 1,590,592, and have been of ¾ inch, ⅞ inch, and 1 inch rods, according to their situations and the duty required of them. The rods used for these rivets would extend to upwards of 100 miles lineal. The roadway is covered with buckle plates, bent by the firm with their own powerful hydraulic machinery. The weight of the iron used in the bridge is about 6,000 tons. If all the pieces of iron employed in the structure, girder plates, struts, ties, buckle plates, etc., exclusive of the rivets, and irrespective of the width of the pieces, were laid end to end, they would extend to a length of 250 miles. The whole of the work for the riveting has been drilled, not a single rivet-hole having been punched. We have heard that the Government, or official authorities in the Punjaub concerned with the erection of the bridge, have expressed their satisfaction with the materials and workmanship. The whole was completed in London-yard in eighty-six weeks. —*Engineering.*

ORDNANCE AND NAVAL.

The "Bessemer."—Those of our readers who have read the accounts of the trial trip given in the daily papers, will probably be disposed to thus summarize what they have read :— The swinging saloon does not yet swing, the "Bessemer" does draw more than eight feet of water, her speed is very much less than twenty miles an hour even in fine

weather, and she is not adapted for the present French harbors because of her great length, and consequent liability to be swung round by the tide. So much, apparently, has performance fallen below promise, that some of our contemporaries have gone so far as to say that the "Bessemer," whatever else she may be adapted for, cannot be used successfully as a passenger boat between Dover and Calais until there is a larger and better harbor made on the French side. We are, at present, far from any such conclusion as this, and so we think will our readers be after hearing what can fairly be said on the other side of the question.—*Nautical Gazette.*

STEAMERS FOR HAYTI.—Messrs. Nefie & Levy, of Philadelphia, have on hand two war steamers for the Haytian Government. The steamers are being built of wood, and the contract for their hulls have been sub-let to Messrs. Birely, Hillman & Streaker. The larger of these two vessels will be of 700 tons burthen, and she will be 190 feet long by 32 feet beam, and 14 feet depth of hold. The vessel will be fitted with direct-acting horizontal engines of the surface condensing type, with cylinders 38 inches in diameter and 24 inches stroke. Both engines and boilers are to be completely surrounded by coal bunkers, as a protection against shot and shell from an enemy. The steamer's armament will consist of an 11-inch Rodman gun amidships, two 30-pounder Parrott rifles at either end, and two broadside 32-pounder smooth bores. The smaller vessel will be 158 feet long by 29 feet beam and 12 feet depth of hold. Her engines will be of the same type as those of the other steamer; the cylinders will be 32 inches in diameter by 20 inches stroke.—*Engineering.*

THE *Borsenzeitung* says that it is to be decided in the course of the present summer whether the two gunboats built for service on the Rhine are to form the nucleus of a gunboat flotilla to be permanently established on that river. The gunboats in question, together with the two French ones which were captured in the second battle of Orleans, will make various trial trips on the river for the purpose of ascertaining whether the establishment of such a flotilla would be desirable. It is not proposed to use these boats for any other object than to strengthen the defences on the Rhine, and if the creation of a flotilla should be determined upon it will be divided into squadrons to be attached to the various fortresses. The reason of this is that the difficult navigation of the Upper Rhine and the strong currents in that part of the river would make it almost impossible to send the boats up the stream. On the Lower Rhine, however, between Cologne and Coblenz, a single squadron will be sufficient to provide for the defence of the whole of that section of the river. The French gunboats are covered with plates from five to eight centimetres thick, and have engines of forty horse power. They draw from 1.1 to 1.25 metres of water, carry a sixteen or twenty-four centimetre gun and a light field gun or mitrailleur, and have crews of from twenty-six to forty-five men. The armament of the new German gunboats is not yet decided on.—*Engineer.*

WE noticed some time ago, says the *Pall Mall Gazette*, the force and originality of the views which Admiral Porter took occasion to impress upon his countrymen in the annual report on the United States' Navy. Those of his suggestions which referred to the construction of a single small but efficient ironclad squadron, backed by a few swift corvette cruisers, to supersede the present antiquated and almost useless vessels on the list, remain still in abeyance. But the late votes of Congress have been applied partly to another, the improvement of the offensive torpedo service. Admiral Porter avowed his belief that torpedoes used merely passively would greatly disappoint their designers; and he even satirised the late experiments made by projecting them from the bows of slow, worn-out steamers. But he expects great things from a bold use of these weapons offensively by properly constructed vessels, and the new torpedo steamer, the Alarm, lately launched at Brooklyn, is the first attempt to give practical effect to his views. As in the case of the Dantzic torpedo boats of Germany, speed is a special object, and the lines are consequently fine and the engines powerful. But the Alarm is over 300 tons measurement, thus many times larger than the similar models of the Baltic builder, and is to carry one very heavy gun as a reserve, in case her torpedo boom falls, with Gatling guns for her own protection from boat attacks. As she is built with a wheelhouse, this, as well as her size, will prevent her having the comparative invisibility on which the German inventors much rely for the efficiency of their squadron. But, on the other hand, the Alarm is constructed to face a sea in which their low and fragile vessels would be quite useless.—*Engineer.*

LIGHTHOUSES AND WRECK-SIGNALS.—Owing to the wreck of the "Schiller," and to the absence of any means of making it known to the shore by the men in charge of the Bishop Rock Lighthouse, many suggestions have been made, amongst others, that a telegraphic wire should be laid between the Bishop Rock Lighthouse and the land, and that a similar arrangement should be made in the case of all other detached lighthouses. It appears to us that there are four objections to this. The first is, that vessels would be more frequently tempted to approach the lighthouses for the purpose of reporting themselves, and thus actually run into proximity to danger. The second is, that a telegraphic cable would, in such a position among rocks and breakers, be speedily liable to damage and even destruction, and would, at the best, be untrustworthy; the third is, that the occasions when such a wire might be useful would be so extremely rare (for it certainly must not be used for any other purpose than as a distress signal) that from disuse the keepers would have difficulty in remembering how to work it, and the apparatus would be very liable to get out of order; and the fourth is, that a telegraph wire is really unnecessary for the purpose. The Marine

Department of the Board of Trade have had manufactured for them by the War Department a new sort of rocket, which the department has named a "call" rocket. It is to be used only when a ship is seen to be in distress, wanting assistance from the shore. At present the "call" rocket has been supplied to light ships only, but we would throw it out as a suggestion whether it should not be also supplied to outlying lighthouses like the Bishop Rock. It is a day signal as well as a night signal, and is quite distinctive. No one can possibly mistake it for any other rocket or signal. It reaches an altitude of 2,500 feet, carries up with it a very large charge of powder, which explodes with a great noise, and also shows both in its upward and downward course a very powerful magnesium light.— *Nautical Magazine.*

BOOK NOTICES.

THE YEAR BOOK OF FACTS IN SCIENCE AND ARTS FOR 1874. Edited by C. W. VINCENT, F. C. S., etc. London: Ward, Lock, & Tyler. For sale by Van Nostrand. Price, $1.25.

THIS is a fresh issue in a new cover of a very old and well-known annual. Mr. Timbs, its originator, has unfortunately departed, but his mantle has descended upon Mr. Vincent, who has rehabilitated and thrown fresh vigor and force into a very valuable book. There were indications in the recent volume that Mr. Timbs' sources of information were narrow and few, but Mr. Vincent has gone wider and further afield, and the value of the book is enhanced accordingly. It is a very useful work of reference.—*Telegraphic Journal.*

HAND BOOK OF LAND AND MARINE ENGINES. By STEPHEN ROPER, Engineer. Philadelphia: Claxton, Remsen & Haffelfinger. Price, $3.50.

This work includes the moulding, construction, running and management of engines and boilers. It is a compendium in convenient form of the miscellaneous information required by the engine builder or engine driver.

Besides descriptions of many of the leading forms of engines, there are minute directions for the adjustments of those parts which the young engineer needs most to learn at once. There is no attempt to be philosophical on the part of the author, but the information given is straightforward and plain talk rather brief.

PRACTICAL HINTS ON THE SELECTION AND USE OF THE MICROSCOPE. By JOHN PHIN, Editor of the Technologist. New York: Industrial Publishing Co. For sale by Van Nostrand. Price, 75 cts.

The use of the Microscope is rapidly extending. Whether used for popular amusement or popular instruction its value is beyond all computation superior to that of the telescope. Every school should have a compound microscope, and every pupil old enough to feel interested in natural science should learn to use one.

How to select an instrument, and how to collect and observe objects is exceedingly well told in this little book. We recommend it to all who have not access to the larger manuals.

THE YOUNG SEAMAN'S MANUAL, COMPILED FROM VARIOUS AUTHORITIES FOR THE USE OF THE U. S. TRAINING SHIPS AND THE MARINE SCHOOLS. New York: D. Van Nostrand. Price, $3.00

The title of this book explains its scope. The minuteness of the information can be judged from the topics treated in separate chapters; they are as follows, viz: I. The Compass and Lead; II. Knotting and Splicing; III. The Log; IV. Rope; V. Blocks; VI. Tackles; VII. The Mast—The Rudder; VIII. Cutting and Fitting Rigging; IX. Masting; X. Rigging Ship; XI. Sails; XII. Boats.

The book is eminently fitted for the purposes of instruction. The typography is excellent, with all technical terms printed in heavier type than the context, and the whole illustrated by 350 good cuts.

THE ENGINEERS, ARCHITECTS, AND CONTRACTORS' POCKET-BOOK FOR THE YEAR 1875. London: Lockwood & Co. For sale by Van Nostrand.

THIS has been long known as "Neale's Engineers' Pocket-Book," and has been jointly prized for the extent and accuracy of its information.

A new edition appears yearly, but the changes in the more valuable portions of the volume are few or none. The calender and lists of officers of scientific societies, of course, are changed for each new year.

A yearly pocket-book of formulas is presumably freer from typographical errors than other similar works in that portion of the book which is reprinted year by year, as each new edition is a new opportunity for correction. Such, we believe, to be the merit of this pocket-book.

PRIME COST KEEPING, FOR ENGINEERS, IRONFOUNDERS, BOILER AND BRIDGE MAKERS, &C., PRACTICALLY EXPLAINED, WITH THE METHOD OF ARRIVING AT ALL THE GENERAL AVERAGES REQUIRED. By JOHN WALKER. Liverpool: Dunsford & Son.

Nothing is more essential to the prosperity of an engineering establishment than the employment of an efficient system of keeping the prime cost accounts, and this being so we are glad to notice the publication of the useful manual now before us. Mr. Walker appears thoroughly familiar with his subject, and he treats it in full detail, giving sample pages of the books suitable for keeping the accounts of the different departments of an engineering works, and explaining the mode of preparing general averages and getting out the total costs of articles involving different classes of work. Altogether the book is calculated to be very useful to those who have not an efficient system of prime cost keeping in operation at their establishments.— *Engineering.*

HINTS TO YOUNG ARCHITECTS. By GEORGE WIGHWICK, Architect. A New Edition, revised and considerably enlarged, by G. HUSKISSON GUILLAUME, Architect. London: Lockwood & Co. For sale by Van Nostrand. Price, $1.40.

An examination of this book shows that it forms a material extension of the work upon which it is founded. Thus Parts IV., V., and VI., comprising about a hundred pages, are entirely new, while other parts of the book have received many additions and revisions. The three first parts of the work refer respectively to the school studies, studies abroad, and early practice of a young architect, and contain numerous hints and suggestions of value. Then come the three new parts already mentioned—these dealing with the principles of construction, sanitary construction, and design—and lastly, we have a model specification, which appears to have been well revised in accordance with modern practice. The book is one well calculated to be of service to the class for whom it has been written.—*Engineering.*

EUROPEAN LIGHT HOUSE SYSTEMS. By MAJ. GEO. H. ELLIOT. New York: D. Van Nostrand. Price, $5.00.

This report is the result of observations made during a tour of inspection in 1873 under the direction of the Light House Board. The writer seems to have been exceedingly well qualified both for the inspection and for the report of it, and the result is a work interesting to an exceptional degree.

Fifty-one engravings and thirty-one wood cuts illustrate the work; all are well executed.

In summarizing his preliminary report which forms a preface to the complete work, the author says: "While the British and French systems are necessarily very much like our own, I saw many details of construction and administration which we can adopt to advantage, while there are many in which we excel. Our shore fog-signals, particularly, are vastly superior both in number and power. They are in advance of us in using both the gas and electric lights in positions of special importance; in the use of horizontal condensing prisms for certain localities; in the character of their lamps; in the use of fog-signals in light-ships; in their light-ships with revolving lights, and more than all, in their character of their keepers, who are in service during good behavior until death or superannuation, who are promoted for merit, and whose lives are insured by the government for the benefit of their families."

The report has already been widely commended.

HYDROLOGY OF SOUTH AFRICA; OR, DETAILS OF THE FORMER HYDROGRAPHIC CONDITION OF THE CAPE OF GOOD HOPE AND OF CAUSES OF ITS PRESENT ARIDITY. By JOHN CROUMBIE BROWN, LL.D. Kirkaldy: John Crawford.

THIS work offers testimony bearing on a question of great interest, viz.—possible changes in the moisture of the climate of a section of country and the probable causes of the change.

The work is divided into three distinct parts, which are not divided in chapters and sections. The "parts" treat respectively of—

I. Former Hydrographic Condition of South Africa.

II. Cause or Occasion of the Desiccation of South Africa.

III. Aridity and Water Supply of South Africa.

In conclusion the author holds that corresponding accounts might be given of the hydrology of other lands, and that appropriate remedies are the erection of dams to prevent the escape of a portion of the rainfall to the sea; the restriction of the burning of the *veldt;* the consummation and extension of existing forests; and the adoption of measures similar to the *reboisement* and *gazonnement* carried out in France with a view to prevent the formation of torrents, and the destruction of property occasioned by them.

A large portion of the work is compiled from standard writers on physical geography.

A TREATISE ON RAILWAY SIGNALS AND ACCIDENTS. By ARCHIBALD D. DAWNAY, Assoc. Inst. C. E. London: E. & F. N. Spon. Price, 80 cts. For sale by Van Nostrand.

MR. DAWNAY has chosen for this treatise a subject on which little has been written, while that little is to be found chiefly in the Transactions of scientific societies which are not accessible to the general public. The popular description of railway signaling to be found in the volume before us is, therefore, likely to be appreciated. Commencing with an account of the earlier forms of signals or semaphores used for communicating intelligence, Mr. Dawnay proceeds to describes the numerous varieties of signals now in use on the railways of this country, his explanations being illustrated by numerous engravings. The second part of the work is similarly devoted to descriptions of the various forms of locking gear and systems of electric signaling, while in the third the author treats of railway accidents due to defective signaling, his record being a very interesting one.

The fourth part of Mr. Dawnay's treatise deals with the defects of signaling arrangements as frequently carried out, and contains suggestions for improvements. These latter are of a practical kind, and have apparently been well considered. The author is evidently well acquainted with his subject, and he enters into its details carefully, and without showing any prejudice in favor of particular schemes. With his remarks on the habitually loose working of the block system on many lines we thoroughly agree, and we have on numerous occasions condemned the policy which renders such working possible and even necessary. Altogether Mr. Dawnay has produced a very interesting and useful treatise, which we have pleasure in recommending to all interested in railway signaling.—*Engineering.*

A PRACTICAL TREATISE ON THE SCIENCE OF STEAM. By N. P. BURGH. Part I. London: N. P. Burgh. For sale by Van Nostrand.

Mr. Burgh is adding another to the long list of his "practical treatises." We have now before us the first part, containing two excellent plates—the best feature all our author's works—and eight pages of letterpress. We regret that Mr. Burgh does not pay a little more attention to correct modes of expression,

exactness of language being absolutely essential in scientific literature. Old and hackneyed theories, however, are wholly discarded, and even Galileo and Tyndall are left behind by our author, who explains latent heat thus:—"Electricity is at the bottom of it all, but to what extent and how that property is upheld and mantained by the Great Creator is beyond our wisdom." The wonderful effects of heat are thus described:—"Heat also is a most powerful agent, as for example, it will reduce solids to ashes, and also form liquids, and cause the latter to evaporate as a vapor with a small sediment behind. In fact, heat is the reverse of cold, while both are governed by the same law." Perhaps the most remarkable statement in the part is an explanation of the generation of steam in iron boilers. In some cases, it appears "*the flame passes through the plate* in a filtered form, and forms steam with the water." The explanation of this fact—which our author does well to express in italics—is, that "there is a space filled with vaporised water between the top surface of the plate and the bottom of the water. The flame then ignites this vaporised water, and it becoming lighter than the volume above, ascends and heats the surrounding currents it passes through." Mr. Burgh has only to fully corroborate this to establish his claim to be considered one of the most remarkable discoverers of our century!—*Iron*.

MISCELLANEOUS.

CASTING METALS.—Messrs. Farnsworth & Sanson, of Mansfield, has patented some improvements in apparatus used in forming moulds for the casting of metals. According to the invention, the moulding table is formed with a true surface, and is fitted to receive the moulding boxes and the mould plate. The moulding boxes used are fitted with pins on one half and holes in the other, and are all in duplicate. The patterns are secured to a pattern plate, and are capable of sliding through the mould plate, the forms of the one being exactly the counterpart of the other, so that the sand is prevented from being pulled down in the withdrawal of the pattern. The pattern plate is capable of being slid up and down in the framing, and is operated for this purpose by a pinion acting on a rack to the table, such pinion being actuated by ordinary gear and hand wheel or other means.

HAND PUMPS.—Mr. J. Davison, of South Shields, engineer, has patented an invention which relates to the removal of dead centres in crank shafts, and is effected by keying on to a straight longitudinal shaft, supported in journals, a hollow barrel with solid ends. This barrel is divided diagonally and spirally into two portions, and so set apart from each other as to permit a pin to travel to and fro on the shaft and between and along the divided edges of the two portions. Connected to the external end of the pin is an upright arm fixed to the cross-head that works on a centre below the barrel. When the pin is driven to and fro along the shaft by the revolution of the barrel, the pin carries with it the upright arm of the cross-head, causing the sum to oscillate, and by that means giving motion to the pump rods attached to the two horizontal arms of the cross-head.

THE *Revue d'Artillerie*, published by order of the Minister of War in France, contains the report of Major Bobillier, of the artillery, on the experiments made last year at Creusot in steel, for the construction of cannon. The object of M. Schneider was, of course, to produce a metal that should be free from the faults of both cast iron and bronze, and, according to the report, this object has been obtained; for, in the words of a communication made by General Morin to the Paris Academy of Sciences, on the last day of August—"On the one hand accidents like those which caused the Russian Government to reject a whole material of artillery from the famous establishment of Essen are not to be feared with the soft steel tried at Creusot; and, on the other, the three pieces of 78 m. 6 m.—310 in.—experimented on, supported without reaching the limit of their power of resistance, and without being deformed, nearly as much as bronze would have done under the same circumstances, the most severe trials, and to which guns of the calibre are never submitted in ordinary service." The experiments are still being pursued, but General Morin told the Academy that it might be safely asserted that the establishment at Creusot possessed the necessary elements for the production of cannon in steel, with all the qualities demanded for artillery, namely, resistance against fracture and deformation.

TWO very curious articles have been published by a Shanghai native newspaper, the *Hwei-Pao*, protesting against the construction of railroads in the Chinese Empire. The *Hwei-Pao* is of opinion that the existence of railroads in Europe is too recent to admit of a judgment being formed as to their practical utility, and, moreover, that there is not sufficient business in China to render them profitable. The Chinese journal goes on to say that "tea and silk are the principal objects of commerce, and these have hitherto been forwarded to the treaty ports by river steamboats. A substitution of railroads for steamboats would not effect any saving in point of time, and could not, therefore, even from the point of view taken by the foreigners themselves, be of any service to China. Admitting that a little time was gained, the Chinese would not be benefitted, for the goods would not be exported more rapidly. Thus the railroads would only lead to an accumulation in the ports of vast quantities of goods which, as they would not be shipped off all at once, would fall considerably in price." The *Hwei-Pao* also says: "The accidents on the railroad lines are very numerous, caused by collisions, by the engines or tenders taking fire, by the trains running off the lines, or by bridges giving way and the trains being precipitated into the rivers below. In other cases the carriages are injured by the great speed at which they are car-

ried along, and the accidents are so numerous that it is often impossible to ascertain the exact number of dead and wounded. All the foreign journals are full of details concerning these accidents. But admitting that most of these casualties are preventible, and that the trains follow their regular course, they travel quicker than the thoroughbred horse, and the people walking on the lines would have no time to get off their way. From this cause alone the number of fatal accidents would be enormous. In all countries where railroads exist they are considered a very dangerous mode of locomotion, and beyond those who have very urgent business to transact, no one thinks of using them."

THE HORSE-POWER OF THE WORLD.—Dr. Engel, director of the Prussian Statistical Bureau, has been making estimates on such statistical data as are available of the total horse-power of steam engines in the world, as every country has tolerably correct railroad statistics. Dr. Engel thinks that the following returns with reference to locomotives are not far from right:

	Year.	Number.
United States	1873	14,223
Great Britain	1872	10,933
Zolverein	1871	5,927
Russia	1873	2,684
Austria	1873	2,369
Hungary	1869	506
France	1869	4,933
East Indies	1872	1,323
Italy	1872	1,172
Holland	1872	331
Belgium	1870	371
Switzerland	1868	225
Egypt	1870	212
Sweden	1873	185
Denmark	1865	39
Norway	1871	34
Total		45,467

It may be assumed that there are still four or five thousand additional locomotives in countries from which no statistics have been received, so that something like fifty thousand engines of that description, of an aggregate of 10,000,000-horse power, all now in use. Dr. Engel estimates all the engines in use, locomotive, marine and stationary, at about 14,400,000-horse power.

ROTARY PUDDLING FURNACES.—Messrs. Jones, of Middlesborough, have patented some improvements in rotary puddling furnaces. The invention consists—1. In admitting water intermittently to the space between the casings of the furnace (when the furnace is composed of 2 casings) by various modes or contrivances, one mode being by means of valves or cocks; another method is by means of scoops or bent pipes, or in some cases by a coil of pipes or annular space or duct formed round outside of the revolving furnace; and another plan by means of buckets arranged at intervals around and attached to the outside of the outer casing.—2. In effecting the egress of the water from the water space of the rotary furnace by means of pipes, channels, or ducts, one or more of which are coiled round the outside of the outer casing, and communicate at one end with the water space.—3. In forming the rings which are secured round the ends of the furnace (and which are divided into two or more segments) with recesses on their outer faces respectively, which recesses fit over corresponding projections on the outer faces of the rings against which the furnace rings revolve, and serve to maintain a tight joint and to prevent the waste of cinder and iron thereat; also in connecting the water-pipes (which are cast in the bodies of the rings) at their external ends outside the furnace with the water space between the casings by means of branch pipes or connecting pipes.—4. In constructing the cast iron or steel end of a single-cased rotary furnace in two or more pieces or segments which are respectively attached to the circular flanged end of the furnace by bolts, and to each other by internal or external flanges and bolts.

DIMENSIONS OF THE EARTH.—Two German scientific men, Messrs. Behum and Wagner, have recently published the results of some very accurate measurements that they have made respecting the dimensions of the earth. From these it appears that the length of the polar axis is 12,712,136 metres, that of the minimum equatorial diameter, which is situated 103 deg. 14 min. east of the meridian of Paris, or 76 deg. 46 min. west, is 12,752,701 metres, whilst the maximum diameter at 13 deg. 14 min. east, and 166 deg. 46 min. west, is 12,756,588 metres. They estimate the total surface of the globe at 509,940,000 square kilometres, whilst its volume is equal to 1,082,860,000,000 cubic kilometres. The circumference of the globe on its shortest meridian is 40,000,098 metres, whilst that of the longest is 40,069,903 metres. The oceans and glaciers occupy 375,127,950 square kilometres. The total number of inhabitants of the earth is estimated at 1,391,000,000—viz., 300,530,000 in Europe, 798,000,000 in Asia, 203,300,009 in Africa, whilst the population of America is 84,542,000 and that of Oceana 4,438,000. The population of the towns and cities exceeding 50,000 inhabitants is 69,378,500, or about one-twentieth part of the total population of the globe, leaving nineteen-twentieths of the inhabitants for the villages and smaller towns.

THE change of proprietorship of the *Evening Star* and the issue of the paper from the office of the *Glasgow News* were announced by 1,025,000 little hand-bills, which were printed in the incredibly small space of half an hour. Such a feat of rapid printing, we believe, has never before been performed, and it would have been impossible to perform it but for the Walter Press. The process was interesting. The small hand bill, measuring three inches by two, was reproduced by stereotyping to the extent of 336 times, and by 4,000 revolutions of the Walter Press the million bills were printed. It occupied ten hours to cut them up with a steam guillotine machine, and they were distributed throughout the town from the windows of two carriages.